JOURNAL OF THE
SOCIETY OF GLASS TECHNOLOGY

JOURNAL

OF THE

SOCIETY OF GLASS TECHNOLOGY

COMPRISING

PROCEEDINGS AND REPORTS, TRANSACTIONS

AND

ABSTRACTS OF PAPERS FROM OTHER JOURNALS

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1923.   Vol. VII.

The Society of Glass Technology.

THE SOCIETY OF GLASS TECHNOLOGY was inaugurated at a meeting in the University of Sheffield, on Thursday, November 9th, 1916.

Its object was defined as the general advancement of the various branches of Glass Technology by the association of persons interested in glass and glassware; the reading and discussion of papers; the publication of scientific information on glass technology; the formation of a library and museum.

All persons or associations of persons interested in glass, whether from the point of view of the manufacturer, the distributor, the scientist, the user or collector, are eligible for membership.

Membership is of three classes : Collective Membership, open to Firms, Associations, and Committees; Ordinary Members, and Student Members, the annual subscription in each class being £3 3s., £1 10s., and 2s. 6d. respectively. Copies of the Constitution and Rules may be had on application to the Secretary, The University, Sheffield. The total number of members whose election has been confirmed exceeds 650.

Meetings of the Society are arranged monthly, except during the summer. One half of the meetings take place at Sheffield, the headquarters of the Society, the other meetings being held in different centres of the glass industry, as the Council decides. In this way local interest is stimulated.

The Society publishes a Quarterly Journal, containing the papers read to the Society and the discussions on the papers, together with abstracts of other papers of interest to members published in British and foreign journals. Each collective member may receive two copies and each ordinary member one copy.

Scientific communications on glass technology are invited for publication in the Journal.

A library of technical literature has been formed, and a list of the books available for reference or for loan may be obtained from the Secretary.

The Society of Glass Technology

LIST OF OFFICERS FOR 1923-24.

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SOCIETY OF GLASS TECHNOLOGY

PROCEEDINGS OF THE FIFTY-EIGHTH MEETING.

HELD in the Applied Science Department, the University, St. George's Square, Sheffield, on Wednesday, January 17th, 1923, at 3.0 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the Chair.

· A cordial welcome to the meeting was given to Mr. H. L. Dixon, of Pittsburgh, an American member of the Society. The President referred briefly to the many kindnesses Mr. Dixon and others had shown to the party of members of the Society who visited America in 1920. Mr. Dixon replied.

A paper, entitled, " Stainless Steel, with some Consideration of its Application in the Glass Industry," was given by W. H. Hatfield, D.Met. It was illustrated by experiments and lantern slides, and was followed by a discussion to which there contributed the President, Messrs. J. H. Davidson, W. C. Snowdon, R. Hemingway, V. F. Gloag, and G. Simpson.

A paper, illustrated by lantern slides, entitled, " Some Measurements of the Viscosity of Glasses near their Annealing Points, and a Critical Review of some Recent Literature on the Annealing of Glass," was given by S. English, M.Sc. Lack of time prevented discussion of this paper.

During the forenoon a party of members paid a visit to the works of Messrs. Thomas Firth and Sons, Ltd., Weedon Street, Tinsley, Sheffield.

An opportunity of having tea together was provided after the meeting.

The following were elected Ordinary Members :—

1. Tamesaburo Yamamoto.	*President*, Yamatame Glass Co., Japan, and *Managing Director*, Japan Beer and Mineral Spring Co.
2. Pancras J. Schoonenberg.	*Manager*, Messrs. Philips' Glowlampworks, Ltd., Eindhoven, Holland.
3. Edward Hardy Sweeting.	*Works Assistant*, Messrs. E. Breffit & Co., Ltd., Glass Works, Castleford.

PROCEEDINGS OF THE FIFTY-NINTH MEETING.

HELD in Armstrong College, Newcastle-upon-Tyne, on Wednesday, February 21st, 1923, at 2.45 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the Chair.

A vote of thanks was accorded to the Directors of Messrs. Lemington Glass Works, Ltd., and to Mr. W. W. Warren, A.M.I.C.E., A.M.I.E.E. (General Manager), for their courtesy in allowing members to visit their works during the forenoon.

Mr. WARREN replied briefly, saying that they would be glad to extend similar facilities to members of the Society on future occasions.

A vote of thanks was also accorded to the authorities of Armstrong College for their courtesy in providing accommodation for the Society's meeting, and for allowing members to use the College Refectory after the meeting.

The PRESIDENT directed attention to the "Roll of Members" and to the "Suggestion Book."

A paper, entitled, "Organising for Production from Pot Furnaces" was read by Mr. W. W. Warren, A.M.I.C.E., A.M.I.E.E. In the discussion that followed there took part the President, Messrs. F. G. Clark, T. Teisen, G. Barras, T. W. Ferry, and W. Butterworth.

The last two papers on the agenda were taken together and presented by Prof. Turner, namely, (a) "The Effect of Boric Oxide on the Melting and Working of Glass," by F. W. HODKIN, B.Sc., and Prof. W. E. S. TURNER, D.Sc.; (b) "Some Physical Properties of Boric Oxide-containing Glasses," by Violet Dimbleby, B.Sc., S. English, M.Sc., and Prof. W. E. S. Turner, D.Sc. These papers were illustrated by specimens and by lantern slides. A discussion followed, to which there contributed Messrs. A. L. Marden and W. Butterworth. Prof. Turner replied.

The following were elected Ordinary Members :—

1. Wilfred Frank Dines.	*Manager*, Pottery Department, Messrs. B. Laporte, Ltd., Luton, Beds.
2. Charles Baylis Fox.	123, Rosendale Road, Dulwich, London, S.E. 21.
3. Francis W. Jones.	c/o Messrs. G. E. C. Glass Works, Wembley, Middlesex.

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VISIT TO THE WORKS OF MESSRS. THOMAS FIRTH AND SONS, LTD., TINSLEY, SHEFFIELD.

ABOUT twenty-five members of the Society paid a visit to the above works during the morning of Wednesday, January 17th, 1923, and witnessed methods of producing stainless steel. They were first shown several electric furnaces in action, each of about ten tons capacity. The tapping of one of these furnaces by a process of tilting, and the casting of ingots proved a most interesting experience. A great contrast was provided by the old crucible-steel process in which crucibles, each holding only about 50 to 60 lb. of steel, were heated in furnaces beneath the floor level. This latter method is still the most suitable for the production of certain kinds of steel such as high carbon tool steels. The visitors afterwards witnessed the rolling and hammering of stainless steel and the casting of small articles, such as bath taps, etc.

Shaping and toughening mild steel motor-car springs by heating and then immersing in oil, and the manufacture of saw blades, were other processes displayed to the visitors.

VISIT TO THE WORKS OF MESSRS. LEMINGTON GLASS WORKS, LTD.

DURING the morning of Wednesday, February 21st, 1923, a party of members of the Society had an opportunity of visiting the works of Messrs. Lemington Glass Works, Ltd. Members were met by Mr. W. W. Warren, A.M.I.C.E., A.M.I.E.E. (General Manager), and Mr. G. W. Barras (Works Manager). An instructive time was spent observing the processes in the manufacture of electric lamp bulbs and of glass tubing. The bulbs were made both by the hand process and by means of a recently installed 24-arm Westlake machine. Of recent installation also was a 10-pot Hermansen recuperative furnace. The grouping of the hand workers round the **D**-shaped furnaces attracted the special attention of the visitors. The importance of the grouping and methods of working adopted were emphasised by Mr. Warren in the paper he presented to the Society at the afternoon meeting, his subject being " Organising for Production from Pot Furnaces."

SOCIETY OF GLASS TECHNOLOGY.

MEMBERS' CHANGES OF ADDRESSES.

The addresses in the following lists are to be substituted for those appearing in the "List of Members" dated December 1921. Since the latter was published, the following members whose names appear therein have died.

J. Frank Bottomley, Ph.D.
Preston M. Bruner.
A. H. Heisey.

Harry J. Powell, C.B.E., B.A.
Alfred Wilson.

COLLECTIVE MEMBERS.

Crystal Glass, Messrs., Ltd.	Corner of King and Clarence Streets, Sydney, New South Wales, Australia.
Miller, Messrs. Wm. J.	*Manufacturers of Glass-making Machinery,* Swissvale, Pa., U.S.A., and 12/13, Henrietta Street, London, W.C. 2.
Powell, Messrs. J., & Sons (Whitefriars), Ltd.	Wealdstone, near Harrow, Middlesex, and 98/100, Wigmore Street, London, W. 1.

ORDINARY MEMBERS.

Adamson, J.	c/o Messrs. Automatic Bottle Makers, Ltd., Trafford Park, Manchester.
Adamson, Robert.	49, Raglan Street, Newport, Mon.
Arnold, H.C., B.Sc., M.A.	4020, McKee Avenue, St. Louis, Mo., U.S.A.
Bourne, T. L.	Messrs. Spencer Lens Co., Hamburg, New York, U.S.A.
Brook, Miss M., B.Sc.	58, Church Road, Tovil, Maidstone.
Bruner, Louis N.	c/o Messrs. American Express Co., 6, Haymarket, London, S.W. 1.
Clark, Walter Gordon.	*Consulting Engineer,* 8, West 40th Street, New York, U.S.A.
Clarke, G. Wilson.	Brow Foot, Ulpha, Broughton-in-Furness.
Coad-Pryor, Eric A., B.A.	*Director of Laboratories,* Messrs. British Glass Industries Ltd., Charlton, London, S.E. 7, and 14, Hayes Way, Beckenham, Kent.
Cooper, George W.	*Publisher,* 50, Church Street, New York, U.S.A.
Currie, John, M.A.	67, Grange Road, Alloa, and Messrs. Scottish Central Glass Works, Ltd., Alloa.
Davis, C. N.	1244, 29th Street, San Francisco, U.S.A.

Foxon, J. E.	*Production Manager*, Messrs. United Glass Bottle Manufacturers (Charlton), Ltd., London, S.E. 7, and 136, Colcraine Road, Blackheath, London, S.E. 3.
Haig, Wilfred George.	"Belmont," Park Road, West Smethwick, Staffs.
Hemingway, Ralph.	37, Garden Street, Mexborough.
Hill, James Grainger.	269, Stourbridge Road, Harts Hill, Brierley Hill, Staffs.
Hodgkin, A. E., M.C., B.A., A.I.C.	c/o Messrs. Brunner, Mond & Co., Ltd., Northwich, Cheshire.
Howes, H. W., B.Sc.Tech.	"Dunvar," Kinghorn, Fife.
Hughes, Gibbard.	Great Hampden, Great Missenden, Bucks.
Inman, G. E., B.S.	Nela Park, East Cleveland, Ohio, U.S.A.
Jackson, Fredk.	Messrs. Fredk. Jackson & Co., Ltd., Laboratory Furnishers, 44, Chapel Street, Salford, Manchester.
Johnstone, E. G.	Messrs. Macgregor, Caldbeck & Co., 1, Rangoon Street, Crutched Friars, London, E.C. 3.
Kamita, Kiyoshi.	Research Laboratory, Messrs. Asahi Glass Co., Ltd., Kikuicho, Ushigomeku, Tokyo, Japan.
Kerr, C. H., Cr.E.	417, East 2nd Street, Moorestown, N.J., U.S.A.
Kitson, T. B.	Trafalgar Buildings, 1, Charing Cross, London, S.W. 1.
Kjellgren, S.	Rejmyra, Sweden.
Lamplough, F. E., M.A.	47, Bunbury Road, King's Norton, Birmingham.
Laycock, John E.	Messrs. John Kilner & Sons, Ltd., Calder Vale Glass Works, Wakefield.
Loomis, G. A.	Messrs. Ohio Valley Clay Co., Steubenville, Ohio, U.S.A.
Mann, John.	*Glassworks Engineer*, 221, Park Road, Barnsley.
Mayhew, W. H.	*Sub-Manager*, Messrs. Chance Bros. & Co. Ltd., Smethwick, Birmingham, and 19, Jesson Street, West Bromwich.
Nutting, P. G.	109, South Church Street, Schenectady, N.Y., U.S.A.
Ota, Hirotaro, B.A.	*Research Laboratory*, Messrs. Asahi Glass Co., Ltd., Tokyo, Japan, and No. 20, Nakacho, Ushigome, Tokyo.
Parker, W. B., F.I.C.	*Chief Chemist*, Messrs. British Thomson-Houston Co., Ltd., Rugby, and 1, Murray Road, Rugby.
Pasotti, F. G.	*Engineer*, Messrs. British Glass Industries Ltd., Stephenson Street, Canning Town London, E. 16.
Paterson, C. C., O.B.E., M.I.C.E., M.I.E.E., F.Inst.P.	*Director*, Research Laboratories, Messrs. General Electric Co., Ltd., Wembley, Middlesex.

Peddle, C. J., M.B.E., D.Sc.,
F.I.C.

Richardson, Elwood A.

Ridley, W. T.

Russell, Frank, F.G.S.

Saxton, C., A.M.I.E.E.

Searle, A. B.

Snowdon, W. C., B.Sc.Tech.

Stephens, Percival B.

Stone, H. H. H.

Travers, M. W., D.Sc., F.R.S.,
F.I.C., F.Inst.P.

Washburn, Prof. E. W., S.B.,
Ph.D.

Whatmough, W. A., B.Sc.,
A.I.C.

White, H. B.

Winship, Wm. W.

Winwood, Henry.

Wood, W. F. J., C.B.E., B.Sc.,
F.I.C.

Youldon, Fredk.

Zeal, G. H.

23, Barnstaple Road, Thorpe Bay, Essex.

Messrs. Libbey Glass Manufacturing Co.,
Toledo, Ohio, U.S.A., and Box 919,
Toledo.

c/o Messrs. F. W. Berk & Co., Ltd., 1, Fen-
church Avenue, London, E.C. 3.

Messrs. General Refractories Co., Ltd.,
Kelham Island, Sheffield, and Auldam
House, Worksop.

Engineer, Talbot House, Arundel Street,
Strand, London, W.C. 2.

Consulting and Analytical Chemist, 440,
Glossop Road, Sheffield.

c/o Research Laboratories, Messrs. General
Electric Co., Ltd., Wembley, Middlesex.

9, Harlech Street, Dewsbury Road, Leeds.

Office Manager, Messrs. United Glass Bottle
Manufacturers (Charlton), Ltd., Charlton,
London, S.E. 7, and 5, Clarendon Road,
Holland Park Avenue, London, W. 11.

Messrs. Travers & Clark, Ltd., Waldorf
Chambers, 11, Aldwych, London, W.C. 2,
and 52, Scarsdale Villas, London, W.

The National Research Council, Washington,
D.C., U.S.A.

" Kildare," Friern Watch Avenue, Finchley,
London, N.

Grosvenor Rest, Medstead, Hants.

Manager, Messrs. Thermal Syndicate, Ltd.,
Borden Building, 350, Madison Avenue,
New York, U.S.A.

c/o A. Harris Esq., Barnsley Road, Cud-
worth.

Messrs. Wood Bros. Glass Co., Ltd., Ponte-
fract Road, Barnsley, and Park House,
Barnsley.

Portland House, 73, Basinghall Street,
London, E.C. 2.

Clinical Thermometer Manufacturer, 77, St.
John Street, Clerkenwell, London, E.C. 1.

CHANGE OF NAME.

Hartford-Empire Company (formerly Hartford-Fairmont Company),
Manufacturers of Glass-Working Machinery, Hartford, Conn., U.S.A.

PROCEEDINGS OF THE SIXTIETH MEETING.

HELD in the Latin Theatre, The University, Edmund Street, Birmingham, on Wednesday, March 21st, 1923, at 2.45 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the chair.

A report from the American Treasurer, Mr. Wm. M. Clark, announcing the death of Mr. Preston M. Bruner, St. Louis, Missouri, who was elected a member in November, 1921, was received with regret.

A vote of thanks was accorded to the authorities of the University of Birmingham for their courtesy in providing accommodation for the Society's meeting.

A vote of thanks was also accorded to Messrs. Austin Motor Co., Ltd., for welcoming a party of members at their Longbridge works during the morning.

The SECRETARY read the following letter from the American Ceramic Society :—

AMERICAN CERAMIC SOCIETY,
LORD HALL,
COLUMBUS, OHIO.
February 15*th*, 1923.

DEAR MR. CLARK,

The Board of Trustees regrets very much that a survey of conditions here and abroad makes it seem unwise for this Society to attempt to organise a party for visiting England and the Continent during the summer of 1923.

Your invitation, and the services you have rendered in this connection, are very much appreciated, and we regret that we cannot carry the plans to full fruition. At some later date we hope that it will be possible for a goodly sized party of Ceramists from America to visit England, and certainly we wish it known by you that we have a welcome for you whenever you will visit this country.

Yours very cordially,
(Signed) ROSS C. PURDY
(*General Secretary*).

It was Resolved—

That the Secretary be instructed to write to the American Ceramic Society expressing regret that the proposed visit to this country would not take place this year, to say that the invitation still remained open, and to assure their American

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friends that a hearty welcome awaited them whenever the invitation could be accepted.

The PRESIDENT intimated—

(a) That the Annual General Meeting would be held in Sheffield on April 18th.

(b) That the Annual Dinner would be held in London on May 16th.

(c) That the proposed exhibition had been postponed from April to October, 1923.

The PRESIDENT directed attention to

(a) The Roll of Members.

(b) The Suggestion Book.

(c) The " Directory for the British Glass Industry."

A paper entitled " A Rapid Method of Testing the Durability of Glassware," by H. S. BLACKMORE, VIOLET DIMBLEBY, B.Sc., and Prof. W. E. S. TURNER, D.Sc., was presented by Miss Dimbleby, who was thus the first lady to read a paper before the Society. The paper was illustrated by lantern slides, and was followed by a discussion to which there contributed Messrs. J. G. Hill, F. G. Clark, E. A. Coad-Pryor, and Dr. H. B. Cronshaw. Miss Dimbleby and Prof. Turner replied.

The other two papers on the agenda were taken together and presented by Prof. Turner, namely (a) " The Corrosion of Fireclay Refractory Material by Glass and Glass-making Materials," by D. TURNER, B.Sc. Tech., and Prof. W. E. S. TURNER, D.Sc.; (b) " The Effect of Saltcake in Corroding Fireclay Materials," by EDITH M. FIRTH, B.Sc., F. W. HODKIN, B.Sc., and Prof. W. E. S. TURNER, D.Sc. These papers were illustrated by lantern slides. The following members contributed to the discussion :—Messrs. E. A. Coad-Pryor, W. F. Pearson, G. V. Evers, Col. S. C. Halse, Dr. R. D. Bain, and Dr. H. B. Cronshaw. Prof. Turner replied.

The following were elected Ordinary Members :—

1. James Basil Basnett Atherton.   c/o Messrs. Pure Limespar Products, Ltd., 13, State Insurance Buildings, 14, Dale Street, Liverpool.

2. André Gobbe.   *Editor of " Le Verre,"* 10, Rue de l'Industrie, Charleroi, Belgium.

3. Helen Edith Cheyne Irvine, B.Sc.   *Research Chemist,* c/o National Physical Laboratory, Teddington.

4. Lionel Etridge Norton, B.Sc. Tech.   *Works Chemist,* c/o Messrs. City Glass Bottle Co., Ltd., Ford's Park, Canning Town, London, E. 16.

5. Seki Senda.   20, Yoshida-Honmachi, Kyoto, Japan.

6. Stanley Turner, B.Sc. Tech., D.F.C.   Stoneleigh, South Anston, near Sheffield.

7. Edward Bennett.   *Automatic Machine Operator,* 15, Bowness Street, Stretford.

PROCEEDINGS OF THE SIXTY-FIRST MEETING, BEING THE SIXTH ANNUAL GENERAL MEETING.

HELD in the Applied Science Department, The University, Sheffield, on Wednesday, April 18th, 1923, the President in the chair.

The Sixth Annual Report of the Council (together with the Accounts) having been circulated, was taken as read, approved, and adopted.

The Report ran as follows :—

SIXTH ANNUAL REPORT OF THE COUNCIL.

THE membership of the Society on December 31st, 1922, stood at 649. During the year 1922, 46 new members were elected (7 Collective and 39 Ordinary), 11 of whom were resident in the United States.

The statement of membership may be summarised in the following tables, which enable a survey to be made of the geographical distribution of membership.

A. *Total Members elected up to the end of* 1922.

Honorary	1
Collective	155
Ordinary	608
Student	24
	788

B. *Members on the Roll, December 31st,* 1922.

Location.	Honorary.	Collective.	Ordinary.	Student.	Total.
British Isles	1	112	357	2	472
Argentina	—	—	1	—	1
Australia	—	2	2	—	4
Belgium	—	1	1	—	2
Canada	—	—	5	—	5
China	—	—	2	—	2
Czecho-Slovakia	—	1	—	—	1
France	—	5	9	—	14
Germany	—	—	2	—	2
Holland	—	2	1	—	3
India	—	1	11	—	12
Japan	—	2	15	—	17
South Africa	—	1	1	—	2
Spain	—	—	1	—	1
Sweden	—	—	7	—	7
U.S.A.	—	6	98	—	104
	1	133	513	2	649

The foreign membership continues to increase and numbered 177 at the end of 1922. It is noteworthy that for the first time the Society records members in Czecho-Slovakia and Germany, and it is certain that but for the effect of depreciated exchanges in many European countries, a large number of applications for membership would be received and a largely increased sale of the JOURNAL effected abroad.

The losses in membership during the year were considerable, the result of post-war conditions and trade depression.

The Council has to regret the deaths of the following six members during the year :—

Dr. J. F. Bottomley.	Harry J. Powell.
Preston M. Bruner.	Prof. C. W. Waggoner.
Major A. H. Heisey.	A. Wilson.

The following thirty-six members have resigned :—

(a) *Collective* (14).

Aylesford Sand Co., Ltd.
Amalgamated Glass Bottle Works, Ltd. (Dissolved).
John Baird, Ltd.
Barr & Stroud, Ltd.
Boulton & Mills.
Caledonian Bottle Works, Ltd. (Dissolved).
Dennistoun Glass Works, Ltd. (Dissolved).

Down Bros., Ltd.
English Electric Co., Ltd.
J. J. Griffin & Sons, Ltd.
O. C. Hawkes, Ltd.
Hyposol, Ltd.
Queenborough Glass Bottle Works.
Sheraton Glass Manufacturing Co., Ltd.

(b) *Ordinary* (22).

E. Ambrose.
J. B. Arch.
P. B. Arch.
C. Archer.
F. Beddow.
M. L. Burgess.
E. F. Chance.
J. B. Coppock.
F. R. Dixon-Nuttall.
J. Field.
W. Galbally.

F. W. Hampshire.
J. G. Kaufmann.
S. Lamb.
F. Shelly.
A. Smales.
H. J. Stobart.
J. Seddon.
N. Shaw.
F. P. Wainwright.
N. F. Wheeler.
H. B. White.

The Council also took the step of making its list of members a healthy one by removing the names of nineteen members (eighteen ordinary and one collective), through the non-payment, without reasonable cause, of subscriptions due.

In spite of these losses, the total number of members on the roll at the end of 1922 was only fourteen less than at the end of 1921, owing to the continued influx of new members.

At the Annual Dinner, held in Sheffield, the Society had the pleasure of welcoming as guests : The Right Honourable The

Lord Mayor of Sheffield (Alderman Charles Simpson); Sir W. H. Hadow, C.B.E., D.Mus.; Sir Albert J. Hobson, J.P., LL.D., and the Dean of York (The Very Reverend W. Foxley Norris, D.D.).

Of special interest were the October meeting at York (when Dr. W. Foxley Norris, Dean of York, showed members the mediæval glass in the Minster and described the work of restoration), and the November meeting, when presentations of the Frank Wood Medal were made.

During the year arrangements were made for members to have tea together after the meetings in order to encourage social intercourse. The opportunities thus afforded have been found of great value.

In order to stimulate interest among members of the Society resident in France, the programme of meetings for the session 1922–23 was drawn up so as to include a visit to Paris.

The Council has again to record its appreciation of the courtesy extended by several firms in allowing members of the Society to visit their works. The Council cordially thanks the firms in question for the privileges so afforded.

The good relations subsisting between this Society and the American Ceramic Society have been further enhanced by an exchange of advertisements. This Society's advertisement appears in the *Journal of the American Ceramic Society*, while an advertisement of the American Ceramic Society appears in the *Journal of the Society of Glass Technology*.

During the year the Society was invited to nominate a representative on Panel No. 5, " Clay, Glass and Silica Ware, and Refractories," of the British Engineering Standards Association. Professor W. E. S. Turner, D.Sc., was nominated, with Mr. W. J. Rees as alternative.

The sixth volume of the *Journal* contained 51 pages of Proceedings, 25 original papers, contributed to the Society and occupying 308 pages, and 445 Abstracts and Reviews, occupying 335 pages. The total number of pages, excluding advertisements and indexes, was 694, compared with 627 for 1921. This increase of 67 pages was largely due to a very considerable increase in the number of Abstracts and Reviews.

The number of volumes in the Society's Library at the end of 1922 was 230, an increase of 40. The Council would be glad to see the library made use of more extensively by members.

During the year the preparation of the Society's " Directory for the British Glass Industry " was actively prosecuted, but the work involved has been so great that it was not possible to complete it before the end of the year.

The Income and Expenditure Account for the year 1922 shows an adverse balance of more than £50, although the excess of assets over liabilities on December 31st, 1922, amounted to some £60. Analysis of the accounts, however, shows the position to be a very satisfactory one. Thus, the grant of £50 to the Glass Research Delegacy was included in the current year's account instead of in that for 1921, whilst a change in procedure was made, as compared with previous years, by which the sum of £65 9s. received in 1922 for 1923 *Journals* was not treated as Income for 1922. Again, of the Expenditure, more than £20 was on account of the " Directory," for which as yet the Society has had no return. It will thus be recognised that the balance sheet has been conservatively constructed and should lead to a favourable position in 1923. The cost of printing, preparing, and distributing the *Journal* was about £1,150, out of a total income of some £1,600.

SOCIETY OF GLASS TECHNOLOGY.

DINNER ACCOUNT, 1922.

EXPENDITURE.

	£	s.	d.
To Royal Victoria Station Hotel	25	5	0
,, Gratuities	1	10	0
,, Printing	3	15	6
,, Entertainer	2	2	0
,, Bank Charges		2	6
,, Postages		4	9
	£32	19	9

INCOME.

	£	s.	d.	£	s.	d.
By Balance from 1921				23	15	0
,, Tickets Sold (39 at 12s. 6d.)	24	7	6			
Less Returned		12	6	1	2	9
Received from President, re Guests						
Deficit, made good out of General Account				8	1	11
				£32	19	9

SOCIETY OF GLASS TECHNOLOGY.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING DECEMBER 31ST, 1922.

EXPENDITURE.

	£	s.	d.	£	s.	d.
To Abstractors' Remuneration ...				72	15	0
,, Advertising				5	0	0
,, Bank Charges				5	10	6
,, Binding Books and Periodicals ...				6	9	0
,, Binding and Cases for "Journal," Vol. VI., 1922				20	15	0
,, Books and Periodicals ...				13	11	3
,, Deficit on Annual Dinner ...				8	1	11
,, Grant to Glass Research Delegacy				50	0	0
,, Insurance at Bungay ...				6	10	0
,, Meetings Expenses ...				10	11	1
,, Office Expenses				7	18	2
,, Postages, etc.				56	15	4½
,, Printing, etc., of "Journal" No. 21	286	14	2			
No. 22	268	9	5			
No. 23	223	2	2			
No. 24	229	6	0	1007	11	9
,, Printing Excerpts, "Journal" No. 21	14	15	0			
No. 22	15	8	3			
No. 23	9	19	9			
No. 24	13	14	5			
,, Printing Notices and Stationery, etc.				53	17	5
,, Salaries				91	7	2
,, Travelling Expenses ...				240	0	3
,, Telephones				5	2	0
,, Refunds of Cash ...				3	2	0
,, Repurchase of "Journals"				4	10	0
				2	5	6
				£1671	**13**	**4½**

INCOME.

	£	s.	d.	£	s.	d.
By subscriptions :						
(a) Collective ...	362	5	0			
(b) Ordinary ...	495	0	0			
(c) Student ...						
(d) American ...	136	5	6			
(e) Odd Amounts ...	14	16	1			
(f) In Arrears paid up	22	16	0	1031	4	7
,, Bank Interest ...					12	
,, Binding Cases Sold						
(1) To Members ...	5	12	0			
(2) To Non-members		9	0	6	1	0
,, Commission on Advertisements in "Journal," 1922 ...				316	0	0
,, Journals Sold						
(i) To Members ...	60	8	8			
(ii) To Non-members ...	185	6	7	245	15	3
,, "Refractories Specifications" Sold						
,, Registration Fees						
,, Balance, being Excess of Expenditure over Income ...				59	18	0½
				£1671	**13**	**4½**

SOCIETY OF GLASS TECHNOLOGY.

BALANCE SHEET AS ON DECEMBER 31ST, 1922.

LIABILITIES.

	£	s.	d.	£	s.	d.
Abstractors' Remuneration				72	15	0
Advertising				1	5	0
Binding and Cases for "Journal," Vol. VI, 1922 ...				20	15	0
Printing, etc., of "Journal" No. 24	9	19	9	229	6	0
Printing Excerpts, "Journal" No. 23	13	14	5			
No. 24				23	14	2
Journals for 1923 Sold in advance to Non-members						
Subscriptions for 1923 paid in 1922 ...				122	10	6
Balance from 1921 Balance Sheet ...	65	9	0			
Less Deficit as per "Income and Expenditure A/C"	16	11	0			
	59	18	0½	62	12	5½

£492 7 7½

ASSETS.

	£	s.	d.	£	s.	d.
Cash in Hand, Sheffield				401	16	7½
" Bank, Sheffield				10	7	6
" Bank, U.S.A.					6	0
Commission on Advertisements, "Journal" 24				412	10	1½
Journals in Stock at Bungay :—				79	17	6

Journals in Stock at Bungay :—

No.		No.		No.	
No. 1	—	No. 9	51	No. 17	191
" 2	62	" 10	44	" 18	199
" 3	46	" 11	70	" 19	188
" 4	33	" 12	41	" 20	200
" 5	—	" 13	185	" 21	443
" 6		" 14	194	" 22	444
" 7	9	" 15	207	" 23	448
" 8	20	" 16	201	" 24	432

	Bound Copies		Binding Cases	
Vol. I.	82.		60	
" II.	24.		25	
" III.	138.		20	
" IV.	162.		20	
" V.	185.		40	

Also 200 of Nos. 21, 22, and 23 in sheets for Binding.

£492 7 7½

We have audited the above Balance Sheet for the year ending December 31st, 1922, with the Books, Accounts, and Vouchers relating thereto, and certify it as being in accordance therewith.

DENNIS WOOD, M.B.E., F.S.A.A.
EDWARD MEIGH, M.B.E., M.Sc.

March 10*th*, 1923.

Mr. FRANK WOOD, C.B.E., B.Sc., F.I.C., Past President of the Society, proposing a vote of thanks to the authorities of Sheffield University for their courtesy in providing accommodation for the Society's meetings from time to time, said it was a great honour and a very great pleasure to him to be asked to propose this vote of thanks to the University of Sheffield, and particularly to the Department of Applied Science. They all knew that ever since the Society was founded the University and the Department had been kindness itself and had always given them housing free of charge, which was a very great thing, and he was sure he was only expressing their feelings when he thanked the University for all they had done.

The Vice-Chancellors in turn, Mr. H. A. L. Fisher, afterwards their friend Dr. Ripper, and later Sir Henry Hadow, as well as Mr. W. M. Gibbons the Registrar, Sir Albert Hobson, and all the Professors in the other Departments of the University had always taken the keenest interest in their Society. They owed a very deep gratitude to the Department and to the various Professors and officers, and he was sure they all felt it a great honour that Dr. Ripper had spared a few minutes to visit them that afternoon, because he had always helped to the very best of his ability. He had not spared himself in any way, and had attended deputations all over the country to help the Society and the Department of Glass Technology. Dr Ripper really embodied the whole of the Department of Applied Science, and he was very pleased to see him present, not only because of his great technical knowledge, but also for the charm of his personality. He hoped he did not think him presuming when he said all these things to him, but he assured Dr. Ripper they did appreciate all he had done for them.

Prof. W. RIPPER, C.H., D.Eng., D.Sc., M.Inst.C.E., Dean of the Faculty of Engineering, replying, said he was sure he was made of stone if he did not feel some embarrassment in replying to the very gracious and kindly speech of Mr. Wood. He had attributed a great deal of merit to the University and to the staff of the University, but he (Dr. Ripper) felt that whatever they had done was only what they were placed there for. Their business was to encourage and to help scientific efforts in every way possible, and when the staff of the University did not do that it was time it was swept out. The Society was only thanking them for what was just their common business. Nevertheless, it was a great joy to know that any services they might have been able to render were appreciated in such a way.

He thought the glass industry was one which particularly reflected the influences and effects of the war. For example, they had

learned very early indeed the extreme importance of the application of scientific knowledge to all industries, and none felt it more so than did the glass industry. He did not know of any industry that had responded more splendidly to that demand. He did not think there was any Society with a finer record—which was very largely due to their own President—of response to that obvious demand of the times for the application of science to the industry. The way in which they produced their JOURNAL and the quality of the contents of that JOURNAL, all did the Society very great credit indeed; and they at the University did not omit to take notice of the splendid work that was being done. It fully repaid him and his colleagues for anything they might have done and they felt that some of the glory of the Society's work was reflected on the University. As a University, they had really taken a very keen interest in all Dr. Turner's efforts, and as far as he knew the University, they might be sure that there would be no falling off of that keenness of interest. He thought these Societies not only got members together to discuss the scientific aspects of their industry, but helped them to follow what was happening up and down the country and to lead in turn to other developments.

He noticed that to-day they had some papers on organisation, administration, and subjects of that kind. The war had taught them the extreme importance of the organisation of their industries, although when the war was over they also discovered it was possible to have too much of a good thing.

It must not be forgotten, however, that good organisation was an enormously important thing, and was becoming more and more so, as also the necessity for training in organisation, and the necessity for comparing notes one with another and of learning what was the best system.

Besides organisation, there was another thing which they could not help noticing in their industries to-day, namely, the tremendously increased attention to the human side of it. There was a growing recognition of the human factor as between labour and capital, as between manufacturer and manufacturer, as between trade society and trade society; in all these ways they were learning the necessity of realising what was the value of the human side as distinguished from merely the scientific side or the financial side. The tendency was, he thought, instead of cut-throat competition, that had done so much to spoil some of their industries, to substitute a certain degree of co-operation, by the comparing of notes, and by mutually helping one another, whether in scientific development or in improved organisation. Such methods tended to develop the general well-being of the industry, and if they were learning to

have regard for the general universal well-being of the industry, they might be sure that this was going to be productive of enormous effects. It was only by mutually helping one another, like members of a family, that our country could attempt to compete with other countries, and societies like the Glass Society were the means through which these helpful suggestions could be made. Every officer of this Society from the President downwards who did anything to bind the Society together, to increase the interest that was felt among the members for the general work of the Society, was doing greater things than he knew.

On the PRESIDENT's motion it was resolved that there be sent to Mr. Connolly (General Treasurer to the Society) a cordial message of sympathy with him in the death of his wife.

The PRESIDENT reported that two Vice-Presidents of the Society, Dr. C. J. Peddle and Mr. W. J. Rees, had recently undergone operations for appendicitis. Happily both were progressing satisfactorily.

It was resolved—

That Rule 18 be amended (by the addition of the words in italics) so as to read—

" The Annual Subscription shall be as follows :—

(a) Collective Members shall pay £3/3/0 per annum ;

(b) Ordinary Members shall pay £1/10/0 per annum ;

(c) Student Members shall pay 2/6 per annum ; *provided that in the case of Ordinary Members, the subscription for manual, clerical, and junior technical workers in the industry shall, subject to regulations to be made from time to time by the Council, be* £1/1/0."

The Meeting then proceeded to the election of Officers for the year 1923–24.

The PRESIDENT intimated that Mr. F. Graves Clark had been compelled on account of ill-health to resign his position as Honorary Secretary, and that Mr. S. English, M.Sc. had been nominated in his place.

For Ordinary Members of Council, six persons were nominated for five vacancies and a ballot took place. Messrs. A. Cousen and D. Robertson acted as scrutineers.

The following lists contain the names (1) of Officers whose term of office expired, and (2) of Members who were elected in accordance with the Rules of the Society to fill the vacancies.

(1)   (2)

President.

Prof. W. E. S. TURNER, O.B.E.,   Prof. W. E. S. TURNER, O.B.E.,
D.Sc., M.Sc., F.Inst.P.   D.Sc., M.Sc., F.Inst.P.

Vice-Presidents.

W. Butler.

Prof. W. G. Fearnsides, M.A., F.G.S.

J. Forster, O.B.E.

Major W. L. Foster, C.B.E., D.S.O.

E. A. Coad-Pryor, B.A.

W. J. Gardner.

Ordinary Members of Council.

E. A. Coad-Pryor, B.A.

W. J. Gardner.

J. Kaye, M.A., B.Sc., F.I.C.

Col. T. W. Simpson.

F. B. Towers.

F. F. S. Bryson, M.B.E., M.A., B.Sc., F.Inst.P.

Violet Dimbleby, B.Sc.

Major G. V. Evers.

Col. S. C. Halse, C.M.G.

Th. Teisen, B.Sc., C.E.

Treasurers.

Joseph Connolly (General).

Wm. M. Clark, Ph.B. (American).

Joseph Connolly (General).

Wm. M. Clark, Ph.B. (American).

Secretary.

F. Graves Clark.

S. English, M.Sc., A.I.C.

Auditors.

Edward Meigh, M.B.E., M.Sc.

Dennis Wood, M.B.E., F.S.A.A.

Edward Meigh, M.B.E., M.Sc.

Dennis Wood, M.B.E., F.S.A.A.

On the motion of Mr. Frank Wood, seconded by Mr. J. H. Steele, a vote of thanks was accorded to the retiring Officers of the Society for their services during the past year.

The Secretary reported that the Council, after careful consideration, had decided to postpone the proposed visit to Paris.

The President directed attention to—

    (a) The Roll of Members.

    (b) The Suggestion Book.

    (c) The " Directory for the British Glass Industry."

The Secretary read a letter from the Institute of Physics, London, inviting members of the Society to be present at a lecture to be given by Dr. J. W. Mellor on May 9th, the subject being " The Application of Physics to the Ceramic Industry."

Prof. W. E. S. Turner's Presidental address was taken as read. His subject was " The Year in Review in the World of Glass-making."

A General Discussion then took place on " Works Organisation."

The subject was opened by Mr. W. W. Warren, A.M.I.C.E., A.M.I.E.E., who gave a *résumé* (with additions) of the paper he had already read at the Newcastle meeting on February 21st, 1923, on " Organising for Production from Pot Furnaces." To the discussion that followed there contributed the President, Messrs. W. Butterworth, G. Simpson, F. F. S. Bryson, J. R. Clarke, E. D. J. Robertson, R. Hemingway, and F. G. Clark. Mr. Warren replied.

Mr. T. C. MOORSHEAD presented the case for Tank-furnace works in a paper entitled " Tank-furnace Works Organisation." To the discussion on this paper there contributed the President, Col. S. C. Halse, Messrs. J. H. Steele, F. F. S. Bryson, and E. D. J. Robertson. Mr. Moorshead replied.

Prior to the meeting, a party of thirty-two members and their friends had lunch together at the King's Head Hotel, Sheffield. A further opportunity for social intercourse was afforded after the meeting, when tea was available for members.

The following were elected members :—

(a) *Collective Member.*

Messrs. Pure Limespar Products, Ltd., 14, Dale Street, Liverpool.

(b) *Ordinary Members.*

1. Milton Asquith.	*Glass Manufacturer*, Messrs. Redfearn Brothers, Ltd., Old Mill Glass Works, Barnsley.
2. Alfred Earl Badger, B.S.	*Physicist*, Glass Technology Department, Messrs. General Electric Co., Nela Park, Cleveland, Ohio, U.S.A.
3. Wilhelm Hodecker.	Messrs. Glasfabrik Sophienhütte, Richard Bock, G.m.b.H., Ilmenau i. Thüringen.
4. James Joseph Moran.	*Assistant Chemist*, Messrs. Kimble Glass Co., Vineland, N.J., U.S.A.
5. Arthur E. Saunders.	*Manager*, Messrs. Dominion Glass Co., Ltd., 388, Carlaw Avenue, Toronto, Canada.
6. Frederick S. Thompson, A.B., Che. Eng.	1133, East 152nd Street, Cleveland, Ohio, U.S.A.
7. Horace Wooldridge.	*Lamp and Glassware Manufacturer*, Messrs. Leeds Flint Glass Co., Ltd., Aire Bank Works, South Accommodation Road, Hunslet, Leeds.

PROCEEDINGS OF THE SIXTY-SECOND MEETING.

HELD in the Physical Chemistry Theatre, University College, Gower Street, London, W.C.1, on Wednesday, May 16th, 1923, the President, Prof. W. E. S. TURNER, D.Sc., in the Chair.

As five papers were available for presentation, a departure was made from the usual arrangements and two sessions were held, a short one at noon, the other at 2·45 p.m.

The first paper presented at the noon session was entitled, " On the Refractive Index Changes in Optical Glass Occasioned by Chilling and Tempering," by F. Twyman, F.Inst.P., and F. Simeon, B.Sc., F.Inst.P. This paper was presented by Mr. Simeon and illustrated by lantern slides. A discussion followed to which there contributed the President, Messrs. V. H. Stott, E. A. Coad-Pryor, and F. E. Lamplough. Messrs. Twyman and Simeon replied.

A paper entitled, " Notes on Burettes," was then given by Mr. Verney Stott, B.A., F.Inst.P. This paper was illustrated by lantern slides and followed by a discussion to which there contributed the President and Mr. F. E. Lamplough.

Votes of thanks were accorded to the authors of the papers presented to the meeting.

At the second session, a cordial welcome was given to Mons. Courty and Mons. Naudeau, who were present as representatives of Mons. Delloye, Paris, who was himself unable to attend. Mons. Delloye, said the President, was very anxious that the proposed visit to Paris should not be postponed. In view of the information given by Mons. Courty, the Council had reconsidered the whole question and gladly approved of the visit being arranged for some time in July. Full particulars would be announced later.

The death of Sir Albert J. Hobson, LL.D., was recorded with great regret.

The PRESIDENT directed attention to the Roll of Members, the Suggestion Book, and the Annual Dinner.

Particulars were given as to the arrangements for the visit on the following day to the new works at Wealdstone of Messrs. James Powell & Sons (Whitefriars), Ltd.

A cordial vote of thanks was accorded to the authorities of University College for their courtesy in providing accommodation

for the Society's meetings, and allowing members to use the College refectory.

The first paper presented at the second session was entitled, " A New Method of Glass Melting," by A. Ferguson. This paper was illustrated by lantern slides. A discussion followed to which there contributed the President, Messrs. E. P. Taudevin, J. Connolly, W. J. Gardner, and Col. S. C. Halse. Mr. Ferguson replied.

A vote of thanks was accorded to Mr. Ferguson for his paper.

The two other papers on the Agenda were not presented, namely :

(*a*) " The Drying Out and Warming Up of Tank Furnaces," by C. Saxton, A.M.I.E.E.

(*b*) "Notes on the Design of Pot Arches," by Th. Teisen, B.Sc., C.E.

In their place, Mr. S. English, M.Sc., gave a paper entitled, " Natural Sillimanite as a Glass Refractory." This paper was illustrated by specimens and followed by a discussion, to which there contributed the President, Messrs. E. A. Coad-Pryor, F. G. Foster, T. Teisen, C. E. Towers, D. Turner, W. J. Gardner, F. F. S. Bryson, and G. G. Middleton. Mr. English replied.

Members had the opportunity of having tea together in the College refectory after the meeting.

The following were elected members :—

(*a*) *Collective Member.*

Messrs. Australian Glass Manufacturers, Ltd., *Bottle and Jar Manufacturers*, Dowling Street, Waterloo, Sydney, N.S.W.

(*b*) *Ordinary Members.*

Chester Alexander Walworth, B.Chem., *Chemist*, c/o Messrs. Libbey-Owens Sheet Glass, Co., Charleston, W.Va., U.S.A.

Francis Winks,   93, Bridge Street, Worksop.

THE FIFTH ANNUAL DINNER.

THE Fifth Annual Dinner of the Society was held in the Hotel Cecil, London, W.C. 2, on Wednesday, May 16th, 1923, at 7.15 p.m.

The President, Prof. W. E. S. TURNER, O.B.E., D.Sc., F.Inst.P., occupied the Chair. The company included Sir F. W. Dyson, LL.D., F.R.S., Astronomer-Royal, and President of the Optical Society; H. J. C. Johnston Esq., President of the Institute of Clayworkers; Sir Lawrence Weaver, K.B.E., Director, United Kingdom Exhibits, British Empire Exhibition (1924); A. R. Upjohn, Esq., LL.B., Master of the Glaziers' Company; W. F. J. Wood, C.B.E., B.Sc., and M. W. Travers, D.Sc., F.R.S., Past Presidents of the Society; R. L. Frink, Esq., Director, Glass Research Association; and Mons. Courty, Paris. Mr. J. Holland, President of the Ceramic Society, was prevented at the last moment from attending.

The following were the toasts :—

    I. " The King."
        Proposed by the President.
    II. " The Society of Glass Technology."

Mr. H. J. C. JOHNSTON, who proposed this toast, made one of his characteristically witty and yet practical speeches. He said that in the early hours of the morning, as he travelled in the train, with his mind wondering what he might say at the Society's dinner, he was engaged in conversation by a person who expatiated at length on the follies of inventors. The biggest fool of all, his companion thought, was the man who, according to the legend, made unbreakable glass and was beheaded for his pains. He trembled to think of the time when their President or some other man of science should boldly come forward with a recipe for a glass that was unbreakable, for the glass industry without breakages would, he thought, be in just as untenable a position as the Astronomer-Royal would be without stars. There was some analogy, he thought, between the glass industry and the clay-working industry, with which latter he happened to

be connected. Of course, from the point of view of antiquity the clayworker could look down on the glass-maker, for the clayworker could undoubtedly boast of the oldest craft in the world, although glass-making was admittedly an ancient occupation. But there was added interest in the connection between the clay-working and the glass-making industries, because he believed that one of the most plausible theories which had been advanced as to the origin of glass manufacture was that the ancient potter, contemplating the siliceous beads which formed upon his ware after excessive heating, and also considering the action of ashes upon the clay, probably became, thereby, the first glass technologist of the world. There were many resemblances between the pottery and the glass industries, but they were strongly alike in the respect that each exhibited the tendency to arouse poetic inspiration. They were also alike in being made from common raw materials which had poetic thoughts behind them—he had only to mention the " feet of clay " and the " sands of time " to instance that their raw materials had found their way into poetry. He was afraid he could not speak in any way effectively of the romance attaching to the glass industry or of its interesting and chequered history, although he recalled that the glass trade, in 1813, was subjected to a tax of nearly £5 per hundredweight, and that it suffered the indignity of having Excise officers requiring notice of every precise process carried out in the industry, even requiring notice and a licence for the removal of a glasspot from the position in which it was dried. He thought they might feel thankful that they were now living in better times. Coming more particularly to the Society of Glass Technology, the speaker said he admired the breadth of name which the Society had chosen. The word " technology," as he conceived it, included not only the chemistry and the physics of the industry, but also every aspect of the practical portion of the work, whether in connection with the raw materials of the industry or the finished product. The work which the Society had done since its inception in 1916 had, he was sure, been of the greatest possible value to the glass manufacturers of the country as a whole. Since then they had embarked on a new era in this country—an era of State-aided research. Everyone would welcome the interest which the State had taken in regard to industrial research. But whether research was supported by the State and the manufacturers generally, or whether it was supported by the manufacturers alone, it was of the utmost importance that that research should be collective, co-operative, and unified. He hoped that in the glass industry there might be no danger—as there had been in others—that the State-aided research should be in any way antagonistic or detrimental to the private research which had

previously been carried on. The closest unification that was possible was desirable in the interest of all concerned. Proceeding to speak of the Society's President, Prof. Turner, the proposer of the toast said that Prof. Turner's name was a household word wherever the glass industry was known, and he was quite sure that in removing his sphere of usefulness to the presidential chair the Society of Glass Technology had taken a very wise and prudent step. To sound the praises of Prof. Turner before the members of the Society of Glass Technology would be to waste one's breath, because his qualities were so well known and so much appreciated. He wished the Society long life and even greater success in the future than it had achieved in the past.

Prof. W. E. S. TURNER responded. He said he was reminded, sitting as he did between heaven and earth (the Astronomer-Royal was sitting on his right and the President of the Institute of Clay-workers on his left) that there were certain analogies at any rate between the members of the trio. In the first place all three in some ways were dealing with things intangible. For instance, no one had yet been able, so far as he knew, to give a ready definition of what clay was. Similarly, he believed that physicists were not yet agreed upon a definition of the ether of space. His friend on the right—the Astronomer-Royal—was probably content with looking out for strains in it. As for themselves—those interested in glass and its production—they were still quarrelling as to what kind of a substance glass was, and so far as he could see there was very little light to be thrown on the situation. Mr. Johnston had referred to unbreakable glass as the highest likely achievement. It had recently been claimed in Czecho-Slovakia that unbreakable glass had been made. He would content himself with the achievements made in producing fire-resisting glass. So much advance had been made in this direction that in America glass coffins were being manufactured.

There had been suggestions more recently that glass was not quite what it seemed to be—that it had a tendency to crystallise out. But there was this, at any rate, that was common between clay and glass : they both belonged to the class of borderline substances. So far as the glass industry was concerned, he thought that it, like glass itself, would have been difficult to define, certainly as an entity, before the Society came into existence. After seven years, however, they had the pleasure of knowing that there had been developed a sense of corporateness which did not exist in the years 1915 or 1916. For this he thought they were all grateful that the Society had brought them together—manufacturers and suppliers of raw materials alike—and had made them friends. The

Society had pursued a good many activities. He remembered that at the first meeting the first President expressed the hope that the Society would be a society with a journal rather than a journal with a society, but he thought that even their first President would since have realised how far the JOURNAL had helped to make the Society, by bringing into close association glass technologists in all parts of the world. They welcomed with them that evening Mons. Courty, who came over in the name of one of the largest and most important firms of glass manufacturers in France to discuss with them how they might best arrange a programme for a visit to his country. The Society had already been to America ; it seemed only a very short distance to France. It might be thought that they ought to have taken that journey hitherto, but, at any rate, they were hoping now to be able to pay that visit this year, and possibly within a comparatively short space of time. There were two other matters he would like to refer to. One of these was that the Society was always anxious to spread the ramifications of the knowledge of glass technology amongst all classes of persons engaged in the glass industry. It already had a number of workmen who paid their subscriptions and were to be numbered amongst its ordinary members. They wanted to stimulate that interest still further, and with that object the Council had decided that persons who were engaged in manual or clerical operations in glassworks, as well as the junior technical members, should be permitted to come into the Society, if they so desired, at a reduced rate of subscription. The Society was willing to sacrifice part of its subscription in order to encourage the reading of its journal and so foster, by every means possible, the glass industry as a whole. They were at all events anxious that all possible opportunities might be put into the hands of the ambitious glassworker, in order that he might gain knowledge and make progress for himself. Such a desire was all to the good of the industry at large, and the Society was out to promote that good by extending its membership along the lines mentioned. These were not the days when they could wax very enthusiastic about the prosperity of the industry, and at a recent Council meeting, when they had been discussing what steps they might best take to assist the manufacturers, one of the members of the Council suggested that the manufacturers would most of all like a well-filled order book. That certainly would help the situation not a little. But it was no use losing heart. He sometimes wished that a little of the buoyancy —perhaps in some ways it might be thought over confidence—of their American friends might be transferred over here ; that they might be inoculated with something of the same spirit ; that they might import into their outlook a sense of optimism, which would

tend to relieve the dullness of the present situation. After all, it would be better to die in hope than live in melancholy. And this brought him to a point he would like to mention about the 1924 Exhibition. What were the glass manufacturers going to do about this? Why not make a big show? The 1851 Exhibition showed to the world how England could, and did, lead the way. In respect of many of her glass products she gained a first prize, and her products were admired by those who came from far and near to pay the exhibition a visit. Why not look forward to 1924 as an opportunity of showing the world what the British glass industry could do now and what it meant to be in the sphere of glass-making? He sincerely hoped that the glass manufacturers would make a really serious effort in this connection.

He had referred already to the glass industry having been lacking in organisation before 1915 or 1916. He hoped that although glass might have a tendency to crystallise, the Society would not set definitely and crystallise in definite directions; that it would be, not an organisation merely, but rather an organism, living and acting with the power of adjusting itself to serve the interests of the industry they all loved. That was what they were all happy to feel had been the characteristics of the Society up to the present time. He hoped that by the goodwill and good fellowship that it promoted it would continue to be that for many years to come.

III. "The Guests."

The toast of "Our Guests" was proposed by Dr. M. W. TRAVERS, who coupled with it the name of Sir Frank Dyson, F.R.S., the Astronomer-Royal. Dr. Travers said that in art, science, and industry glass was a matter of the first importance. The scientific study of glass was a fascinating problem, and the more so because it was a problem that was exceedingly difficult to handle. In taking up a bit of glass one had to remember that what one had to deal with was *something which had happened*. It was a mixture of things, substances, compounds, which had been melted at a very high temperature and which were in a state of frozen balance. The material was unstable, and therefore they were investigating something which presented problems of the utmost difficulty and obscurity. It was this which made the study of glass technology so fascinating a pursuit. Dr. Travers went on to outline the distinguishing characteristics of some of their guests, taking in turn the Astronomer-Royal, the Master of the Glaziers' Company, the Director of the British Empire Exhibition, the representative from St. Gobain, and lastly Mr. Johnston, the President of the

Institute of Clayworkers. In regard to their friend from France, he would like to say that everyone knew the wonderfully artistic glass which came from that country. France was one of the homes of artistic glass. As regards Mr. Johnston, they welcomed him despite the fact that he was a representative from that refractory or earthy side of the glass industry—the side which made them all shiver. He knew it was not the fault of the refractory materials manufacturers, for he had been assured by many of them that if ever they had to be born over again they would take care to choose an industry which did not deal with glasspots.

Sir FRANK DYSON and Mons. COURTY responded for the guests, and the latter read a rough translation of a letter, the substance of which he had been requested to communicate to the Society at its dinner. This was as follows :—" Paris, May 14. My long-standing friendship with English people and the cordiality which I have always received from your country would have made the participation in your annual gathering extremely pleasant to me. The interest which you have shown to me further adds to my wish to come into touch with you, and thus to bring about a collaboration in the technique of the industry which interests us both. I hope within the early future to see some of you here, and it will be a great pleasure to me to assist you to bring about your proposed visit to France. Our different groups of technical men value very highly the friendship of allied neighbours, and only some weeks ago the English Legation was received by our Society of Civil Engineers, which is proud to number well-known Englishmen amongst its members. I can assure you, gentlemen, that in all circumstances my colleagues and I will give you a most cordial and friendly welcome to France.—Fraternally yours, L. DELLOYE."

This communication was received with acclamation, and Prof. Turner requested Mons. Courty to convey to Mons. Delloye the extreme pleasure which his letter had occasioned, and to express their hope that the visit to Paris might yet be arranged.

An informal toast was also drank to the success of the British Empire Exhibition in 1924, and Sir Lawrence Weaver, in reply, in a racy speech, begged of British glass manufacturers to view the Exhibition, not as a means of booking so many orders, but as a matter of pride and prestige in their own industry. If the matter were approached in this spirit the orders would follow. As to space, he hoped manufacturers would speedily make their applications as sites were being rapidly allotted.

The enjoyment of the evening was enhanced by music and by stories, Mrs. M. W. Travers and Messrs. B. P. Dudding and J. Connolly being amongst those who assisted.

The following members and guests were present :—

Adams, F. W.
Adamson, R.
Atherton, J. B. B.
Bacon, R. F.
Bagley, S. B.
Biram, R. S.
Boam, F. J.
Bryson, F. F. S.
Cauwood, J. D.
Clark, F. G.
Coad-Pryor, E. A.
Coad-Pryor, Mrs.
Connolly, J.
Connolly, Miss
Connolly, Miss E.
Courty, Mons.
Dudding, B. P.
Dyson, Sir F. W.
Edgington, W.
English, S.
English, Mrs.
Ferguson, A., and guest.
Foster, F. G.
Fox, J. Chas.
Frink, R. L.
Frink, Mrs.
Gardner, W. J.
Hailwood, E. A.
Halse, Col. S. C.
Hurlbut, F. A.
Jackson, A. H.
Johnston, H. J. C.
Lamplough, F. E.
Luraschi, A. G.
Mandefield, J.
Mayhew, C.
Meigh, E.
Moorshead, T. C.
Moorshead, W. A.

Naudeau, Mons.
Norton, E. J.
Parkinson, C.
Quine, E.
Riley, Col. Chas.
Saxton, C.
Saxton, Mrs.
" Sheffield Independent " Repre-
    sentative.
" Sheffield Telegraph " Repre-
    sentative.
Simpson, G.
Sinkinson, E.
Smeaton, W. G.
Snowdon, W. C.
Stark, Mrs. M. A.
Stott, V.
Sutcliffe, T. C.
Sutcliffe, Mrs.
Taudevin, E. P.
Teisen, T.
Towers, F. B.
Townsend, H. (" Pottery Gazette "
    Representative.)
Travers, Dr. M. W.
Travers, Mrs.
Turner, Prof. W. E. S.
Turner, Mrs.
Upjohn, A. R.
Wardley, T.
Weaver, Sir L.
Webster, J. H.
Williams-Thomas, H. S.
Wood, W. F. J.
Wood, Mrs.
Youldon, F.
Youldon, Mrs.
Zeal, G. H.
Zeal, H. H.

Total 76.

OBITUARY.

WE regret to announce the death of SIR ALBERT J. HOBSON, LL.D., on April 20th at Sheffield at the age of sixty-one. Sir Albert had been a member of the Society from its commencement.

By the death of Sir Albert Hobson, the glass industry and the cause of glass technology in particular have lost a great friend and warm-hearted supporter. This statement may convey little meaning to many members of our Society, for to them and to the meetings of the Society he was practically unknown, but his quality was realised by those who heard him speak in proposing the toast of the glass industry at the Society's Annual Dinner in 1922. In the world of men and affairs he was known as a steel magnate, the chairman of directors of important undertakings; for his civic work as Master of the Cutlers' Company, as Lord Mayor of Sheffield, as the ablest Chairman the City Finance Committee has ever had, and as President of the Sheffield Chamber of Commerce. At the University of Sheffield he had filled the offices of Treasurer, of Pro-Chancellor, and of Chairman of the Glass Research Delegacy. In wider circles he was known as a frequent adviser to the Treasury, as a former President of the Association of British Chambers of Commerce, and as Chairman of the British Committee of the International Chamber of Commerce. It was at the meetings of this last-named body in Rome in March that, in a plea for arbitration as a method of settling commercial disputes, he made one of the finest speeches in a memorable career, and where also, by working strenuously while in a poor state of health, he brought on the illness which resulted in his death.

To those who knew him he was a constant example of high courage, character, and devotion to duty. A life-long physical disability made walking impossible except for a few yards by the aid of sticks, yet he travelled widely in the interests of commerce and of education.

It may seem strange that a man who had not even a remote business or scientific interest in glass should have been a tower of strength, as he had been for four or five years, to those at Sheffield who are attempting to raise the level of the glass industry. Probably it was the enthusiasm of those who undertook the task and his recognition that it was by no means an easy one that

attracted his attention and support; for he was a man to put his shoulder to the wheel whenever the load was heavy. In his capacity as Chairman of the Glass Research Delegacy at Sheffield, he saw much of the expansion of the Department of Glass Technology, was always a supporter of a progressive policy, and, in these days of severe financial stress, had been ever ready to plead with the University Council to go on shouldering the burden and to assure them that the glass industry would one day acknowledge its debt.

If Sir Albert Hobson was but little known to members of the Society, he was, all the time, one of those unseen powers whose influence, wisdom, and advocacy were being constantly exercised on behalf of the Department of Glass Technology, on the success and welfare of which the work of the Society has hitherto been very largely dependent. The Society therefore owes him grateful remembrance.

W. E. S. T.

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VISIT TO THE WORKS OF MESSRS. AUSTIN MOTOR CO., LTD., LONGBRIDGE, Nr. BIRMINGHAM.

MEMBERS of the Society paid a visit to the works of the Austin Motor Company, Ltd., Longbridge, on the morning of Wednesday, March 21st. Under the guidance of the Company's staff they made a tour of the works, the largest of their kind in the British Empire, covering 53 acres, and utilising 6,000—7,000 horse power. The party was enabled to gain a good idea of the processes which go to the construction of a car. They saw the casting of parts in the steel foundry, where the moulds are made with great rapidity by hydraulic machinery and then filled by streams of dazzling white hot metal melted in three converters. Afterwards, the further fashioning of the parts by means of huge hammers, dropping by their own weight on glowing steel, or by great presses which bend cold metal under a pressure of 400 tons, or again by the latest form of automatic machinery shaping a gear or bevel from start to finish held the attention of the visitors, until they passed on to the orderly assembly of components, and then the completion of the chassis. At a further stage, the visitors saw the building of the bodies, their painting by means of compressed air pistols, and the many processes of upholstering and fitting which go to the " finishing " stage of these widely esteemed cars and lorries, of which 150—200 were being made per week at the time of the visit. Note was made of the accuracy with which the cost of every single operation is calculated and controlled,* a vital feature in the profitable operation of so large a plant.

At the close of the visit the President, Prof. W. E. S. Turner, D.Sc., expressed the cordial thanks and appreciation of the members present and remarked that from their tour of the works they were bound to realise that a modern organisation such as they had just seen was in reality an institute of applied science.

* Members interested in the cost control system in operation at Longbridge should consult a series of articles entitled " Cost Control in the Motor Car and Allied Industries," by L. Perry-Keene, F.C.W.A. (Cost Controller to the Austin Motor Co., Ltd.). These articles appeared in " The Cost Accountant," 2, Nos. 4 to 9 (September, 1922, to February, 1923).

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PROCEEDINGS OF THE SIXTY-THIRD MEETING.

HELD in the Leeds Institute, Cookridge Street, Leeds, on Wednesday, June 20th, 1923, at 2.30 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the chair.

The death was recorded with regret of Mr. James Goslin, of Johannesburg, South Africa.

The PRESIDENT intimated that, with the co-operation of Mons. L. Delloye (Glaceries de St. Gobain), a most interesting programme had been arranged for the visit to France during the first week of July.

A paper, entitled, "Specifications in the Glass Industry," was presented by the President, Prof. W. E. S. TURNER, D.Sc. A discussion followed to which there contributed Messrs. F. Lax, E. D. J. Robertson, F. F. S. Bryson, and J. H. Davidson. The President had to leave the meeting before the discussion began, but he said that he would be glad to reply by letter to any questions members liked to send him. In his absence, the chair was occupied by Mr. F. Lax.

A paper, illustrated by lantern slides, was given by T. TEISEN, B.Sc., his subject being, "Notes on the Design of Pot Arches." To the discussion that followed there contributed Messrs. F. Lax, F. F. S. Bryson, and J. H. Davidson. Mr. Teisen replied.

Mr. S. ENGLISH followed with a paper entitled "Notes on the Ashley Bottle Machine." This paper was illustrated by lantern slides and evoked a discussion in which Messrs. F. Lax, F. F. S. Bryson, and T. Teisen took part. Mr. English replied.

The reading of the fourth paper on the Agenda was postponed, namely, "The Effect of Titania on the Properties of Glass," by A. R. Sheen and Prof. W. E. S. Turner, D.Sc.

Vote of thanks were accorded to the authors of the papers presented to the meeting.

The following were elected Ordinary Members :—

1. Henry John Chesney Johnston.	*General Manager*, Messrs. Leeds Fireclay Co., Ltd., Wortley, Leeds, and *President*, Institute of Clayworkers.
2. Ernest Lunn.	*Glassworks Engineer and Mould Maker*, Messrs. E. Lunn & Co., 52, Mount Street, Glasgow.
3. John Frederick McClain.	*Chemical Engineer*, 722, Cross Street, Harrison, N.J., U.S.A.
4. Edwin Barnes.	*Manufacturing Optician*, Messrs. Priest and Ashmore, Newton Works, Eyre Street, Sheffield.

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THE SOCIETY'S MEETINGS IN FRANCE.*

ANOTHER step was taken in July towards linking up with our members and friends abroad as the result of the visit of a party of thirty odd members and their friends to France. The visit, planned and discussed nine months previously, met with complete success, reflecting a very happy and generous spirit in the hearts of all who took part and excellent organisation on the part of M. L. Delloye (Directeur-Général des Glaceries de St. Gobain, Chauny, and Cirey) and his colleagues in France, of Mons. V. Naudeau (the London representative of this firm), and of our Secretary at headquarters.

The main party journeyed from Victoria on Saturday morning, June 30th, 1923, by Newhaven-Dieppe to Paris, and the weather was so favourable that no sea memories were left but pleasant ones. Other members made their way by various routes, and ultimately in Paris there assembled the following British representatives :

J. S. & Mrs. Atkinson	Messrs. Stein & Atkinson, Ltd., London.
R. F. Bacon	Messrs. Wm. Cory & Son, Ltd., London.
D. Balmain	Messrs. G. Davidson & Co., Gateshead-on-Tyne.
G. E. Bateson	Messrs. Bateson Bros., Liverpool.
H. A. Bateson	Messrs. Bateson Bros., Liverpool.
L. M. Butterworth	Messrs. Butterworth Bros., Ltd., Manchester.
F. G. & Mrs. Clark	Messrs. Beatson, Clark & Co., Ltd., Rotherham.
J. Currie	Messrs. Scottish Central Glass Works, Ltd., Alloa.
S. English (Hon. Sec.)	The University, Sheffield.
C. L. Fraser	Messrs. G. Davidson & Co., Gateshead-on-Tyne.
W. G. Gass	Messrs. Entwisle & Gass, Ltd., Bolton.
W. A. Gordon	Messrs. Kilner Bros., Ltd., Conisboro'.
E. A. Hailwood	Messrs. Ackroyd & Best, Ltd., Leeds.
Col. S. C. Halse, C.M.G.	Messrs. J. Lumb & Co., Ltd., Castleford.
A. H. Jackson	Messrs. Dowlow Lime & Stone Co., Ltd., Buxton.
A. Luraschi	Messrs. A. Luraschi, London.
G. E. Noad	Messrs. J. Moncrieff, Ltd., Perth.

* In drawing up this account the Editor is much indebted to Mr. H. Townsend, the representative of *The Pottery Gazette* who accompanied the party.

W. F. Pearson	Messrs. S. Pearson (West Bromwich), Ltd., West Bromwich.
F. W. Preston	Messrs. Taylor, Taylor & Hobson, Ltd., Leicester.
E. D. J. Robertson	Messrs. J. Lumb & Co., Ltd., Castleford.
T. W. F. Robertson	Messrs Robertson & Russell, Sheffield.
W. S. Robinson	Messrs. Barr & Stroud, Ltd., Glasgow.
V. Stott	National Physical Laboratory, Teddington.
T. Teisen	Birmingham.
H. Townsend	*The Pottery Gazette*, Stoke-on-Trent.
Prof. W. E. S. Turner, (President)	The University, Sheffield.
W. W. Warren	Messrs. Lemington Glassworks, Ltd., Lemington-on-Tyne.
H. Webb	Messrs. T. Webb & Corbett, Ltd., Stourbridge.
F. & Mrs. Youldon	London.

At St. Lazare, a deputation of three, namely, Messieurs Dorsemaine and G. Roy, colleagues of M. Delloye—both of whom remained with the party throughout the week, giving assistance in every possible way in the various journeyings undertaken—and the Secretary of the Chambre Syndicale des Maîtres de Verreries de France, awaited the arrival of the train to offer a welcome to Paris. At dinner the same evening, at the St. James and D'Albany Hotel, we had the pleasure of meeting M. Delloye, a man of simple tastes and great personal charm, who had been responsible ultimately for the organisation of the arrangements in France. Thus the visit opened very happily.

The following day (Sunday) was spent as a free day in Paris and its environs, advantage being taken by the major portion of the party to spend the afternoon in the Palace and grounds of Versailles, which have been rendered all the more historic through the holding of the Peace Conference there and the signing of the 1919 Peace Treaty. Fortunately, it was the first Sunday of the month, and the fountains were playing—an impressive sight, which comparatively few foreign visitors have the opportunity of seeing, owing to the infrequency of the operation, due to the high cost that is entailed.

The Reception by the Chambre Syndicale de Maîtres de Verreries.

On Monday morning, July 2, a formal reception took place by the Chambre Syndicale de Maîtres de Verreries de France, at the offices of that body, 32, Rue de Paradis, which quarter, by the way, is the recognised centre of the glass and china wholesale showrooms of Paris.

An important body of glass manufacturers had assembled from

many parts of Northern France to welcome the English visitors,
each of whom was gracefully received and introduced by M. Léon
Houdaille, the president of the Syndicate, who subsequently voiced
the following official welcome, which he began in the French
language : " Ladies and gentlemen of the English delegation and
gentlemen of my own country,—I am happy to greet here, in the
name of my French confrères, the distinguished representatives
of the Society of Glass Technology, who are to-day the guests of
the Chambre Syndicale des Maîtres de Verreries de France. I
greet equally the eminent savants whose scientific work renders
daily such conspicuous service to the glassmaking industry. Their
presence with us to-day is a precious testimony of the interest
that they take in our beautiful craft. I also thank those members
of our Syndicate who have assembled in these offices to celebrate
the arrival in France of our English confrères, and in order to
prove to them how welcome they are in this house of glassmakers.
The Society of Glass Technology, which we receive here to-day, has
its headquarters at the University of Sheffield, and some of its
most eminent members are with us to-day. The English society
also includes among its members a certain number of our own
compatriots, including Prof. H. Le Chatelier, whom we are par-
ticularly pleased to see present at this gathering, and several
French glass manufacturers, who are at the same time members
of our Syndicate, amongst whom are to be counted Messieurs
Delloye, Despret, Charbonneaux, Thouvenin, and others. And
now, gentlemen, permit me to discard, for the time being, our
mother tongue, in order that I may explain to our English con-
frères in their own language what our Syndicate represents—its
organisation, the problems that it studies from the social, economic,
and fiscal points of view—and to outline simultaneously the
difficulties encountered by our industry by reason of the devasta-
tions of our enemies and the efforts of the industry to rehabilitate
itself."

From this point, M. Houdaille continued his discourse in English.
He said : " Ladies and gentlemen of the British Delegation,—
You are welcome in this Syndicate house of glass-makers. This
is the head office of our Syndicate—a vast organisation which
includes nearly all the French master glass-manufacturers, who
are grouped, according to the specialities of their productions,
in six technical sections, each of which has its own president,
and is an autonomous syndicate so far as concerns the particular
products which it manufactures. The sections include bottles,
mirrors, goblets of all sorts, crystals, flagons, and window panes.
Moreover, a certain number of district groups operate in the bosom

of our main Syndicate, and are composed of manufacturers having common interests as regards labour, supplies, and so on.

" Such, gentlemen, is the general organisation of our association, which studies alike all the problems that are of interest to our industry, whether they be economic, social, or pertaining to Customs duties. The prosecution of these vast aims, although all general problems concerning industry have become very complicated since the war, does not prevent a keen research being made in order that we may embrace such scientific progress as is calculated to improve the technical part of our manufactures.

" After many years of peaceful and regular operation of our industry, which relied on manual labour for the greater part of its production, the glass industry has had to face the complicated problem of mechanical manufacturing, rendered necessary by the scarcity of a form of labour which formerly was plentiful and skilful, but in which the war has left great gaps, and prevented the recruiting of the younger elements. The law of supply and demand has rendered very exacting, as regards wages, all those who have not been attracted elsewhere by professions that are easier in appearance, and which do not demand such a long apprenticeship.

" Social conflicts have also added to the complexity of the situation. It is thus that the ringleaders of the workmen's syndicates found, in the particular situation which I have just communicated to you, a favourable ground for their deplorable propaganda, by which they have managed to draw their followers into frequent conflicts, which were not in the least justified by the position of the French glass workers, who are at present touching very high salaries, and who have seen constant improvements realised in their conditions of work, as, for example, the suppression of the night shifts in all the glass factories using glass melting pots. To this question of labour has been added the economic crisis from which all the European nations have suffered. Once the war was over, the various nations found most of the foreign markets closed to their exploitations. Certain sales disappeared almost completely, as was the case with our champagne bottle industry. The stoppage of the sale of champagne in the Oriental markets, in Russia, and, notably, in America, compelled some of our bottle manufacturers to keep their furnaces idle for several years.

" But, gentlemen, there is another cause which has weighed heavily on the glass industry in France, and that is the systematic destruction of our factories by the German armies. A large number of French glass factories, situated in territories which

were invaded by our enemies in the very first days of the war,
were either entirely destroyed or completely transformed from
floor to roof to suit the needs of the German army. These factories
were returned to their owners after the evacuation in a condition
which rendered all exploitation impossible. The reconstruction of
these factories was, from the very start, hindered by difficulties
of all sorts, and especially by the lack of means of communication
and of transport (the railways had nearly all been destroyed),
want of stocks of raw materials, of coal, and also of working capital
—represented in 1914 by large stocks—which has been pillaged and
smashed by the Germans.

" For the twelve glass factories manufacturing champagne
bottles alone, which were in the zone of hostilities, the damage
done to the buildings and machinery could be valued at 140 million
francs at the present cost of renewal. What would the total be if
one added that of the plate-glass and window-pane factories, the
goblet factories, and the flagon factories, which represented about
forty factories destroyed or out of use ?

" Thanks to the law of 1919, which confirmed the principle of
the solidarity of all Frenchmen in face of the results of the war,
our glass factories have received various indemnities, but of these
the French Government has, up to now, assumed the burden in
the place of Germany, who refuses to pay for her misdeeds. By
this help from our Government, our glass factories have, little by
little, been able to rise again from their ruins. All are not working
again as before the war, but the tremendous effort made by our
glass manufacturers, as well as by the great majority of French
heads of industry, is worthy of mention. It will certainly be more
particularly appreciated in an assembly like the one which I have
the honour to address to-day, composed of the most prominent
figures in the glass-manufacturing industry, and, consequently,
more apt than any other to understand the intense effort furnished
and the energy which had to be shown by our fellow-citizens to
raise, in the midst of such difficulties, so many important establish-
ments from their ruins. The British, who were our brothers-in-
arms on the battlefields, and who helped us to recover our territories
invaded by the enemy, will certainly be pleased to learn of, and to
note, this effort of their French colleagues.

" For our own part, we know of the efforts which have been
made in England to develop and perfect the glass industry. We
realise that many new factories have been built during the last
few years in your country, all of them possessing the latest improve-
ments; we know also of the continuous efforts of the Society of
Glass Technology progressively to increase these improvements

and to make the most of that wonderful product, glass, in all its forms and aspects."

Turning, in conclusion, to his French confrères, M. Houdaille repeated the last paragraph in French, and said that his last word would be to ask his colleagues to join with him in addressing to their English friends their most ardent and felicitous greetings.

PROF. W. E. S. TURNER, responding to the greetings thus expressed, said he was sure that he would be speaking on behalf of every member of the party, and, not only so, but on behalf of every member of the Society of Glass Technology in England, when he said that they were deeply indebted for such an auspicious welcome. On their arrival in Paris the previous Saturday they had received an extremely warm welcome from three of the members of the French Syndicate, and, moreover, from the correspondence which had been passing during recent weeks between the English and the French bodies, they had found numerous evidences of a heartiness and kindness which was proof, if proof were needed, that they were going to be received by friends. He trusted that during the course of the week which had just commenced, as they met one another from time to time in conference, and as they travelled about, they would get into intimate acquaintanceship, and, despite the inevitable small difficulty connected with language, he hoped they would be able to tell one another something of what they were attempting to do in their respective countries to meet and overcome their particular problems.

" We in England," continued Prof Turner, " have not an organisation which corresponds exactly with yours; that is to say, we have not a single organisation which groups together all the various branches of glass manufacture under a single head; but we have a number of associations of glass manufacturers, each of which deals with its own particular branch or section. We have, for instance, an Association of Glass Bottle Manufacturers of Great Britain and Ireland—we still retain the old title—and this Association is by far the largest organisation of glass manufacturers. Then there are several smaller associations also concerned with the manufacture of bottles. We have also an association of flint glass manufacturers, which looks after the interests of those who are engaged in the manufacture of table glassware. There is, likewise, a small association which is concerned with the interests of the manufacturers of chemical glassware; and yet another which looks after the interests of scientific lamp-blown glassware—such apparatus as is blown by the mouth at the lamp on the bench. But all these associations pursue their several ways, and are not united in one large organisation such as yours. Con-

sequently, we of the Society of Glass Technology feel that our body is the only one in which all connected with the glass industry can meet and confer with one another, whatever the branch in which they are engaged may be, although our work is of a technical character. We have here with us to-day representatives of most of these sections, and I hope that all may have an opportunity, so far as time permits, of being able to give you some idea of the problems with which we, in England, are confronted. I believe that in many ways we are at present faced with the same type of problems as you are in France. We always have the problems of labour and wages to contend with. But my friends the manufacturers can say very much more about that subject than I. Happily I have nothing to do with these problems.

" Before I sit down," continued the Professor, " there are two things which I am sure all the members of the party would wish me to say. In the first place, we have not forgotten—and my friend, Mr. Webb, who is one of the manufacturers from the Stourbridge district, would probably have reminded me of the point if I had forgotten to mention it—that in a very large measure we, in England, owe the development of our glass industry to the advent into our country of glass workers from abroad. There was no more powerful influence exerted upon our glass industry than by the glass-makers who came from the various districts of France—Lorraine particularly—in order to settle simultaneously at Stourbridge and at Newcastle-on-Tyne. It was upon the basis of their skill and knowledge that a good deal of the glass industry in England was developed. We have at least to thank you for that. It may be a long way back, yet it was the beginning of a serious development in our glass-making practice. The other matter to which my friends would like me to refer is to say, on their behalf, how much they were impressed by the determination, the character, and the persistence with which our French friends and Allies pursued their way throughout the war, without deflection to the right or to the left, and the manner in which, since the war, they have maintained their determination to rebuild France and her industries. We would like to tell you that we feel the utmost admiration for those efforts and to say that you have our very best wishes for the success of those efforts. We would like to add that if any of the members of your Chamber would care to send up to us any questions, we shall be pleased, through one or another member of our party, to supply the information if we possibly can."

Following Prof. Turner's remarks, individual members of the party rose and gave a brief statement of their respective interests

in the glass industry. Col. Halse (of Castleford) mentioned that he happened to have charge of a glass factory wherein they were endeavouring to develop an entirely new glass-forming machine for which they were responsible. It was perhaps only natural that in such a factory the miscellaneous problems of glass manufacture had taken second place to the development of the machine, but, so far as he had anything to show to the French glass manufacturers, he would be very happy at any time to exhibit it and to give all the information possible.

MR. E. A. HAILWOOD (Ackroyd & Best, Ltd., Leeds), who spoke in French, expressed the sympathy of the English glass manufacturers for the losses which the French manufacturers had sustained as a result of the war. He mentioned that during the early stages of the war he visited Rheims in the hope of finding a glassworks that could supply them with miners' lamp glasses, and he was sorry at that time to discover that the only glass manufacturers in those parts were bottle manufacturers. He had the opportunity of seeing some of the devastation for which the Germans were responsible at that time, for the particular works that he had hoped to visit were in the line of fire, and it was impossible for him to approach them. Formerly his firm had been compelled to purchase most of their glasses for miners' safety lamps from Germany and Austria, and, seeing that they had supplied somewhere about a quarter of all the lamps that were used in Great Britain, it was essential that they should do something to keep the miners of Great Britain supplied. They were eventually forced to the point of putting down a glassworks to make these miners' lamp glasses, and during the war they were fortunately able by this means to supply nearly 70 per cent. of the miners' lamp glasses that were called for in Great Britain. This experience had given them some idea of the difficulties of putting a glassworks into commission, and it enabled him to sympathise very deeply with the French glass manufacturers in their task of repairing the glassworks which had been so wantonly damaged during the war.

One result of this war-time activity on the part of English glass manufacturers had naturally been that, now that the war was over, it was necessary to secure a fair share of trade for the large factories which had been put down. He had visited many countries since the war, but in every case it had been only to find that there was a tariff barrier against the British manufacturer, and this, combined with the difficulties of the exchanges, had led to a good deal of depression in England. Added to this, the British manufacturers were overburdened at the present moment with

taxation. They positively could not continue in this way. He sincerely trusted that something could be arranged between France and England whereby England could have some work to do for France. The French manufacturers had their own specialities : the English manufacturers theirs. He had seriously wondered whether some plan of action might not be decided upon whereby each could get a share of the other's work. It seemed a great pity that there should be so much unemployment at the present time in England whilst British labour was, so far as he had been able to judge, disposed to be reasonable. It was certainly disappointing to have such a large number of excellently equipped glassworks with insufficient orders to keep them going. He was personally acquainted with many directors of industrial concerns in England who, in the effort to keep their hands going, had spent practically all their reserve funds. When one remembered that taxation in Great Britain was still being continued at a terribly high rate— much higher than in other countries which were connected with the war—one could not help feeling anxious for the future. From what he had seen of the conditions in Europe, he could genuinely say that he was sorry that England and America had not backed up France more than they had done in the policy of the occupation of the Ruhr. He was convinced, from a good deal of travel and personal observation in numerous European countries, that the French attitude in regard to the Ruhr occupation was the only attitude which France could adopt in the circumstances.

M. L. DELLOYE, who acted as interpreter during these deliberations, and who spoke exceptionally good English, said that he owed his knowledge of the English language to the fact that he resided in England for two years somewhere about fifty years ago. He said he admired the very frank and interesting manner in which Mr. Hailwood had spoken, but, whilst he was prepared to admit that the situation in England was very critical at the present time from some points of view, there was one point which Mr. Hailwood had made with which he could not be in agreement. He was not prepared to admit that Great Britain was shouldering taxation much higher than was current in France. On that point he could not think Mr. Hailwood had received accurate information. It was true that before the war the taxation in France was very light, but the taxes had increased enormously since the war. They had not only a very high rate of income tax, but all sorts of incidental and miscellaneous taxes. Although the Government, in the first place, said that they were going to impose a very high income tax which would embrace everything else, the French subjects were now finding that they had to pay in taxation nearly,

if not quite, as much as was paid in England. He would be very happy, of course, if the English people had to pay less, but it might be some consolation to know that the French people were not in a very much better situation. Another point—far more serious—was the question of competition between the nations. He could quite understand that, so long as there were so many people out of work in England, it was only natural that the manu- facturers should argue that it was absolutely necessary for them to increase their output and to sell their goods anywhere and everywhere. At the same time, if some definite plan was not decided upon between the competitors of various nationalities, there would be bound to be disappointments and misfortunes for all. Their friends the Belgians—who were, of course, friends of the English also—had contended that it was absolutely necessary for them to sell their glassware productions without restriction in France, but the French and Belgian manufacturers had had a con- ference on the subject, and some sort of agreement had been arrived at.

He would like to remind his English friends that it was rather more difficult to settle a question of this sort with a glass-manu- facturing country like Belgium, because the manufacturers there had special trading connections all over the world. They were mainly an exporting country so far as glass manufacture was concerned. If, therefore, there was a crisis in a country like the United States, for instance, the quantity of glassware that was normally sent to that country became free, and there was a tendency to throw it immediately upon another market. The situation as regards England was better in this respect, because England had a rather more regular trade and experienced fewer booms and slumps, which were extremely dangerous. At the same time, one had to admit that, during the war, England's production had been increased. New works had been established, and it was only natural that they should claim the right to live. The problem at issue was : how could they so combine things that Belgium could have a share of their markets and England a share also ?

M. Delloye proceeded to give an illustration of how, by concerted action, it was found possible some years ago to avert a crisis on the Continent in regard to the plate glass industry. It was dis- covered, he said, that the plate glass industry was losing millions of francs per annum in consequence of over-production. Inter- national correspondence took place on the subject, and a clearing- house was set up in Brussels, where exact statistics were filed regularly in regard to the output of all the works of Europe,

England alone excepted. From this they found out what they already knew, namely, that there was being made about twice the quantity of window glass that could be sold. As a consequence, it was decided to reduce the production and to produce not materially more than was demanded. Prices were fixed, which had to be changed every three months in every individual country, and gradually they succeeded in making friendships between the competitors of the different nations, and at the same time succeeded in saving an industry which had previously been in a very critical situation. He realised, of course, that what they did for plate glass, where the number of works was not particularly large, and where they mostly knew one another, was much easier than might be the case in many other branches of the glass industry. Still, he thought it would be absolutely necessary to find means of getting to know exactly what was going on in the various branches of the glass trade if success was to be grasped in a general sort of way. If the various countries could know just how much they were making and how much they could sell, it would have the effect of preventing any foolish building of new works or increasing of plants where the demand was already met by the supply, and similarly, in the reverse direction, it would lend confidence in the laying down of new plants where the supply was found to be short of the demand. If, on the contrary, every individual country took the view that it must have its share, and increased its productive facilities without any information, there would always be arising dangerous situations somewhere.

Concluding, M. Delloye said that he always considered the English people to be good friends and allies, but it was unreasonable to expect the French manufacturers to go so far as to stop their works in order to make room for English productions. There must be give-and-take in a matter of this sort, but he thought that if things were properly studied together the French manufacturers would be ready and willing to give the English manufacturers what share of trade they could, providing the English manufacturers would be disposed to reciprocate. To obtain good results within a measurable space of time, it would, however, be necessary to set some organisation—some machinery—afoot. The very fact that they met that day under such friendly auspices proved that it was quite possible for them to come into contact and collaboration with one another, and he, for one, would be extremely glad if means could be found for them to come together on this very important issue. He felt that this was the most important point with which he could deal on such an occasion as the present one. He trusted that the British manufacturers

would be willing to consider the matter, and he, on his part, would be quite disposed to provide any information if, in any particular branch or branches of the glass trade, it might be felt that a combination such as he had suggested would be useful and desirable.

The Official Luncheon.

Following the meeting reported above, the visitors were the guests at a mid-day banquet provided by the Chambre Syndicale de Maîtres de Verreries de France at the Hotel Continental. The hospitality was of the warmest, and a sumptuous repast was provided. M. Léon Houdaille presided, and in the positions of honour on his left and right were Prof. H. Le Chatelier and Prof. W. E. S. Turner. The occasion was one that was marked by free social intercourse rather than lengthy speeches. As far as possible the French and English guests were placed at the table alternately, and a splendid opportunity was thus provided for a free exchange of sentiments. Towards the end of the meal the chairman rose and, in the name of the Syndicate, extended a cordial welcome to the English delegates, glass-masters, chemists, professors and experts who, he said, represented there the " brilliant Society of Glass Technology." He desired also to thank particularly the eminent personalities of the French scientific world who had kindly accepted their invitation to the gathering. Amongst the latter were Prof. H. Le Chatelier, whose works were universally known and appreciated ; Dr. A. Granger, the Principal of the Research Laboratory of the National Porcelain Factory at Sèvres ; M. O. Boudouard, Professor of the Conservatoire Nationale of Arts and Crafts ; M. Bertrand, Professor of the Faculty of Sciences and principal collaborator of the Geological Survey of France ; and M. P. Lafon, a collaborator of Prof. H. Le Chatelier. He was happy to express to these gentlemen his gratitude for the service which, by their work, they rendered daily to the French glass industry. They had, unfortunately, to regret the absence of several eminent personalities prevented by various reasons from being present at this banquet. M. Léon Guillet, the President of the Society of Civil Engineers of France, and Director of the Central School of Arts and Manufacturers, had been obliged to go to Brussels, where a reception of civil engineers was taking place ; M. Hayez, Hon. President of their Chambre Syndicale, had found it necessary to go to Douai on business ; M. Léon Appert, Past President of the Society of Civil Engineers of France and Hon. President of the Chambre Syndicale, had had to leave Paris for health reasons ; and several other gentlemen who would have been glad to have been present to celebrate this important visit had been obliged

to send apologies for absence. To these apologies he must add those of a great number of glass-manufacturing colleagues whose factories were scattered over many parts of France, and who were prevented by business affairs from taking part in this auspicious function. The great friendship which united the French and British nations, and which manifested itself in the complete solidarity on the field of battle between the British and French Armies, found to-day a new expression in the brotherliness which caused the English glass manufacturers to accept the invitation of their French confrères and to come in such a representative body to the French capital to talk over with them the relative questions of their industry—their progress, their difficulties, and their hopes of renaissance and development. Their coming to France was particularly appreciated because it was certain that the members of the Society of Glass Technology, who, by their work and researches, had constituted themselves an advance guard of the glass industry, would carry back with them to England the conviction that their French confrères were quite as mindful of the necessary evolution in the operation of their industry, and that they were not, by any means, resting upon tradition or old practices. He trusted that their visitors would take into account in the course of their journeys in France and during their visits to the various works to which they had been invited, all that had been done in the country for the perfecting and development of the manufacture of glass, and that, on their return to England, they would tell their fellow-citizens of the vitality of the French industries, that they would assure them that, in spite of the abominable devastation which was inflicted on a great number of their principal factories, the French people had never been discouraged, and that already nearly all those factories had been raised up from their ruins without any help from Germany, notwithstanding the engagements which she entered into by the Treaty of Versailles. He raised his glass to the prosperity of the Society of Glass Technology and to the continued development of the glass industry.

PROF. TURNER, who responded, said that he might have wished that some glass manufacturer were in his position at that moment, because a manufacturer would best have appreciated the difficulties of the present situation, and would have been able to enter more intimately into the feelings of their French friends and comrades. His own particular line of work was perhaps less harassed by economic questions than that of a manufacturer; at the same time, his work and department had to depend in a very large measure upon an income from the glass manufacturers, and therefore he could only do his work when the glass manufacturers were

operating actively and with some profit. He was sure, however, that the party from England would, one and all, wish him to thank their French friends for their kindness, cordiality and goodwill. The Society of Glass Technology, right from the outset, had never been confined to any particular phase of the glass trade, and very soon after its inception they discovered that its usefulness could extend beyond the borders of England. He was very glad to recall that amongst the very earliest applications for membership which came to them from abroad were applications from their friends in France, and the Society's membership roll now included quite a number of those who were interested in the manufacture of glass in France. At an early stage it was the intention of the Council that they should endeavour to meet from time to time those members who were resident abroad : to visit them, if possible, in their own countries, and in turn to invite them to pay a visit to them in England. They now saw the fulfilment of that hope so far as their French members were concerned. They were glad, in the first place, that this visit fulfilled the idea of the Society to make any and every little contribution possible to the knowledge that was open everywhere to those who were interested in science and technology; and, secondly, because the visit enabled them to realise that the difficulties of one nation in the matter of glass manufacture were very much the same as those of another, with this exception : in England there were no ruined glass factories to rebuild. The problems of actual production were, however, very similar, and it was fitting, therefore, that they should meet together occasionally and confer about these matters. He very heartily thanked the chairman and all those who had been associated with him for the splendid banquet which had been provided to mark their visit. He thanked the President equally for the kind words which he had expressed in relation to the Society of Glass Technology, and for the friendship which had been extended to each one of them individually. All who had had the good fortune to come from England to take part in that gathering would wish him to say, and to close upon this note, that they hoped and believed that the next meeting of this sort would be in England. He trusted that the present gathering would only be the first of a series at which the British and French glass-makers could meet in social intercourse. When a return visit was paid to England, they would have an opportunity of telling and showing their French friends a little more fully what they were endeavouring to do. He had much pleasure in offering their hosts a cordial invitation to England, and he hoped that it might take place in the near future.

Mr. H. Webb, of Stourbridge, associated himself with all that Prof. Turner had said, and confirmed the invitation. He said he was sure they would all be delighted to meet their French colleagues in England and to reciprocate, either in London or "further along," the hospitality which had been extended to them. It might then be possible to resume the conference which had taken place that morning, and explain more intimately some of the troubles and aspirations of the British glass manufacturer.

The Society's Technical Meeting.

At the conclusion of the banquet, a pleasant half-hour was spent in social intercourse in the lounge of the Hotel Continental, and numerous international friendships were cemented. The party then crossed Paris to the meeting hall of the Society of Civil Engineers, 19, Rue Blanche, and the afternoon was spent in the discussion of six interesting papers. Prof. Turner presided over the gathering, and was ably assisted by M. Delloye, who interpreted the various announcements and comments of the Chairman. Three of the papers were contributed by French and the remainder by English technologists. The papers in question were as follows : "Scientific Method in Industry," by Prof. H. Le Chatelier; "Opaque and Coloured Glasses and Ceramic Glazes of the Same Type," by Dr. A. Granger; "The Expansion of Glasses," by M. P. Lafon; "Specifications for Glass Products," by Prof. W. E. S. Turner; "Improvements in the Design of Recuperative Glass Pot Furnaces," by Mr. Th. Teisen; and "The Physical Properties of Boric Oxide Glasses," by Mr. S. English and Prof. Turner.

In thanking Prof. Le Chatelier for reading his paper, Prof. Turner said that all who had been engaged in scientific work for any length of time must know how the name of Prof. Le Chatelier ranked very high in the world of science. The present generation, and those to come, were indebted to him for many findings, both in the realm of what was sometimes referred to as academic science and in the realm of applied science. He had taken a very deep interest in a wide variety of scientific matters, and they were extremely grateful to him for his present paper, in which he had indicated that the problems of applied science, as most manufacturers would know well enough, were exceedingly complex. It was, therefore, highly desirable that they should be tested by laboratory experiments. It was true that the conditions attaching to laboratory experiments could not always be reproduced in a factory. It was quite easy, for instance, to maintain a very tiny furnace at a constant temperature for some time, but with a large

furnace it was quite another matter—a very difficult proposition. It was largely because of this that one encountered so many variable and thorny factors as it became necessary to translate the results of laboratory experiments into actual practical operations. It was important that experiments should take place simultaneously both in the laboratory and in the factories.

Prof. Le Chatelier had done much for industry. To mention two things only which were important for the glass industry, one recalled, first of all, his researches in connection with pyrometry, which had made it possible to obtain methods of measuring high temperatures with some degree of precision; and, secondly, the great interest he had taken in connection with refractory materials for furnace construction. They trusted, therefore, that M. Delloye would kindly convey to Prof. Le Chatelier their heartiest thanks for his address, coupled with the hope that he would permit the Council to have his address for publication in the Journal.

The Visits to Sèvres and to the Etablissement Legras.

On Tuesday morning, July 3, a visit was paid to the National Porcelain Factory at Sèvres, where the members were much interested in seeing the methods adopted in the manufacture of fine pottery. Dr. A. Granger kindly acted as guide, and willingly answered all questions that were put to him.

The same afternoon a visit was paid to the glassworks of Etablissement Legras, at St. Denis, on the outskirts of Paris This is a glassworks manufacturing a big variety of useful and artistic glassware, and, as was explained to the visitors by the managing director, the factory was established many years ago by M. Theodore Legras, now deceased. At the present time it belongs to the concern known as the Société des Verreries de St. Denis et de Pantin Réunies, there being another works, situated at Pantin, belonging to the Société. As was seen in the course of a tour round the works, the company produces many varieties of glassware, including tableware, goblets, tumblers, decanters, chemical glassware for scientific purposes, bottles, and articles of all sizes and shapes for a host of different domestic uses. Quite a proportion of the output is concerned with fancy glassware, painted in enamels, and sometimes gilt finish. Stencilling and sponging is a favourite form of decoration, and the facility with which the paintresses produced some of the decorations was extremely engaging. A few strokes of the brush for a rockery stump or a tree trunk and the main branches, with a few dabs of the sponge to supply the foliage, and there was a picture complete. It reminded one very forcibly of the methods adopted in

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some branches of the pottery trade; indeed, the processes right through in the decorating shops were almost identical.

Formerly the furnaces at this factory were arranged on the Boetius system, but after the war the new company had them transformed, and at the present time all the furnaces are of the Stein recuperative type. The managing director explained that the company is contemplating the construction very shortly of two other furnaces, arranged on the same system, for they had found them to be very economical, and they were aware that recuperative furnaces were also very largely employed in England. Mr. Atkinson, who was a member of the Society of Glass Technology, would be able to give fuller particulars of these furnaces to anyone who required them. Stein & Atkinson's annealing lehrs were also in use at the St. Denis glassworks.

More than 600 workmen are employed by the firm in question, and from what was seen of the men at work they are extremely dexterous and hard-working. It was argued by the management that the work is not now so laborious as it was at one time, for the night shifts have recently been abolished, and this has brought a good deal of relief to the workers generally. The wages that are paid at the present time were considered by the management to be very high.

There was not a great deal to be seen at this particular glass-works in the way of automatic machinery or ultra-modern labour-saving devices. In many respects the factory appeared to be very similar to an ordinary English glassworks. The main impressions that were formed by the visitors were centred round the high degree of craftsmanship possessed by the glass-blowers, combined with the high speed at which they worked.

The Reception by M. and Mme. G. Despret.

After leaving St. Denis, the party crossed the Seine in order to take afternoon tea at the home of M. Georges Despret (Administrator of the Glassworks of Boussois), at 61, Quay d'Orsay. A graceful reception was encountered at the hands of Mme. and Mlle. Despret, and a feature of the visit was the opportunity afforded of inspecting a wonderful collection of artistic glassware, in which the whole family obviously displays a connoisseur interest. This collection must be absolutely unique, each piece having been designed by M. Despret, and made, not for sale, but as an artistic production. The basis of production depends on the use of powdered glass which is heated in a special mould to a temperature sufficient to give a translucent mass. All kinds of tints and colours

are worked in. Some of the pieces take the form of sheets with wonderful landscape effects; others as plaques, two most striking productions being the head of a child in a bonnet and the mask of a woman with fine expression in the eyes. Another remarkable example consisted of a copy in glass of an old Greek marble of the head and shoulders of a child. The specimens were truly a revelation of what can be artistically achieved in glass-making.

A Full Day at Rheims.

On Wednesday, July 4, an early train was taken from Paris to Rheims, and amongst the most interesting experiences of this particular morning must be mentioned a visit to the Pommery champagne cellars, which have a total length of 18 kilometres, with roads and streets running in many directions. Doubtless everyone who took part in the trip will have a greater respect in the future for the champagne industry of France, for few, possibly, had previously realised what a work of care, skill, and patience the manufacture of champagne really is, or the colossal scale on which the industry is pursued, or its import to the glass trade. Millions of bottles of champagne are stored in the cellars, which are cut out of solid chalk, and are reached by descending some hundreds of steps. The settling, de-sedimenting, and corking processes were each demonstrated in turn, and altogether it proved a most informative visit.

The Cathedral of Rheims was also visited, and a brief tour of the city made, a good opportunity being thus afforded of gauging the extent of the war damage and the restoration work involved. Though a tremendous amount of straightening-up has been done during the five years which have passed since the termination of hostilities, it is not difficult for the visitor to estimate the amount of havoc wrought. Although the citizens of Rheims have, by this time, become more or less accustomed to the transformation, they still shake their heads sadly, and remark, " C'est malheureuse ! "

A visit was subsequently paid to the glass bottle works of Charbonneaux et Cie, which is wholly occupied in the manufacture of bottles for the champagne industry. The bottles are made entirely by hand, and to those who visited the works it was emphasised that bottles that are made for the purpose of containing champagne must, of necessity, be able to withstand very high pressures. The contents being much more valuable than the bottle, it is necessary that the utmost care shall be exercised in its formation. For this reason, the company is still adhering to the manufacture of bottles by hand, rather than by automatic

machinery. In other words, they are afraid of taking chances. They feel safe working on present methods and with their present knowledge, and they prefer to remain so. They employ a regenerative tank furnace, fitted with four gas producers. The plant, we were informed, was entirely destroyed by the German army during their incursions; the buildings, too, were all destroyed; but they have been put into tolerably good shape since. At the back of the factory is to be found quite a village of workmen's dwellings, erected on the detached principle. These houses have been built to make good the ravages of the war, which were responsible for the complete demolition of about 40 per cent. of the previously existing workers' dwellings. The position was, of course, an untenable one for a long period, for the houses were within about a mile of the front line. The factory worked until November, 1914, when all the stocks held were disposed of, and the company retired to the centre of France to operate, for the time being, another factory. About 800 workers are now employed, which number represents about two-thirds of the total employees working at the outbreak of the war.

After visiting the factory, the party lunched at the Lion d'Or Hotel, Rheims, and had the pleasure of the company of Madame Charbonneaux and her daughter, Madame Gevignes. M. Emile Charbonneaux, in toasting the Society of Glass Technology, said that it was his great pleasure to bid the members a hearty welcome to Rheims. For the last few years, he said, they had followed with the utmost interest the studies of the Society, and they fully appreciated in France the scientific value of its researches, as well as its firm and matured determination to bring about all the improvements that modern science could make possible in the time-honoured glass industry. He particularly desired to express his thanks both to the technical and industrial personalities standing at its head. He considered it a great honour to have the opportunity of greeting such gentlemen in Rheims that day. " You are paying but a flying visit," proceeded M. Charbonneaux, " to our city, which, as you will have seen, the Germans have almost entirely destroyed. Out of 13,000 houses, 8,000 have been totally wrecked, and 4,000 more or less injured, only a few hundreds being relatively spared. You have seen how, with a stubborn, and quite English-like determination, we have set to work to accomplish the formidable task of rebuilding our town. It has, naturally, taken some time before we could get the estimates ready, the required big loans floated, and all the enormous machinery set in working order. But everything is in full swing now. You have seen houses springing up everywhere, as well as factories

rebuilt, or in the way of being reconstructed, in all parts of Rheims. A large garden city, devised on the same lines as your celebrated English ones, has been provided for the special benefit of families with numerous children. You may realise from this that we are not giving way to depression, and that within a few years a new and active city, full of all resources, will extend again under the shadows of our marvellous Cathedral. I am sure you will carry this thought back to your homes, and I should be delighted if you would think of our town, the seat of so many brands familiar to you, whenever you drink of our famous champagne wine in private or on public occasions. We are keeping quite alive," M. Charbonneaux continued, " the souvenir of those tragic hours when English armies came over to fight side by side with our own armies, and of the prolonged and strenuous efforts which were necessary to prevent the Germans from dictating to the whole world. I personally have twice seen the German troops invade this, my native place—in 1870 and in 1914—but I will never forget that England jumped to our rescue, with the whole of her immense forces, to help us to drive back our invaders. It is, therefore, with a deep feeling of gratitude that I greet heartily all the English friends who have come here to-day to pay a visit to our martyr city. The consequences of the Great War are still weighing heavily upon our allied nations, but we have been closely bound together during the long struggle, and it is my belief that we are not to be less tightly united during the reconstructive period of the Peace. I raise my glass, ladies and gentlemen, to your health, to the Society of Glass Technology, and to the close and permanent friendship between France and England."

PROF. W. E. S. TURNER again had the task of responding. He said that most of those who had undertaken the trip to France had found some new friendships amongst the French people, and day by day their kindness and hospitality seemed to increase. The fact was that they had not realised what their French friends were capable of, and, coming as a surprise, the pleasure was all the greater. Their visit to Rheims had impressed them deeply with the amount of destruction which had been wrought, and he was quite sure that the ideas of most of them, both in regard to the extent of the war damage and in regard to the clearing up of the mess afterwards, had been undergoing a change during the past few days. They had all come to learn something more of the point of view of the French people towards the present attitude of their late enemy, the Germans. They had come to have a better appreciation of all that the war had meant to France, and he thought, after having seen what they had, they would be pre-

pared to go back to England and to second such efforts as would make for a righteous settlement of the Peace. He said this much because, as a man of peace, he certainly had felt, now and again, that it would be almost worth while to have peace in Europe at any price. After the last few days, however, and the conversations that he had had, he confessed that he had begun to see something of the other point of view, and to appreciate the attitude of the French nation. He would like M. Charbonneaux and the other gentlemen whom they had met on the tour to know that, from this aspect alone, the visit had been an education to them. He would also like to thank M. Charbonneaux, on behalf of the Society of Glass Technology, for his kind appreciations of what it had succeeded in doing up to now. He would like to say, if in a slightly different form, what he had endeavoured to say in Paris two days previously. Although, when the Society was founded, its desire was to be of service to the glass industry, it was rather natural that the service had been largely directed towards those engaged in the glass industry nearest to the Society's headquarters, namely, in England. But science, of course, knew no bounds, no nationality; and whatever information and knowledge could be gained by research, that knowledge became public property, and was available for all who cared to take advantage of it. They were delighted, therefore, that amongst the first of the overseas glass manufacturers who desired to join the Society in membership were some of the leading glass masters in France, and it was worthy of mention that to-day the French manufacturers, as a body, represented the second largest body amongst the Society's foreign members, the American group of members being largest. He repeated that they all sincerely hoped that their next meeting would be in England, and they trusted that, whenever that happened, M. Charbonneaux and his wife and daughter would be amongst their guests.

Col. S. C. Halse called upon the members to rise and drink to the health of their host, his wife, and daughter. He would like to express the hope that in the future they would have fewer troubles and much more success than in the past. In the City of London they had rather a nice way, to his mind, of expressing such a toast. There, they would put it in this way : " To the Charbonneaux family : May it flourish, root, and branch ! " The toast was drunk with musical honours, and the party afterwards boarded motor cars in order to visit the battlefields. The route taken was through the destroyed villages of Cernay, Berrin, Nogent, Beisne, Novroy, and Carmillet, returning to Rheims through Fort Pompelle. Train was taken back to Paris at 4.30

in the afternoon, and for many hours afterwards conversations were carried on at the hotel bearing upon the experiences of the day.

At Fontainebleau.

The whole day on Thursday, July 5, was spent in a visit to Fontainebleau, a name that is well known to most people who have visited France, by reason of its ancient and historic interest. Fontainebleau was a royal residence from probably the first century onwards, and the Palace there, which was altered or extended in turn by practically every new monarch, became the favourite dwelling place of Napoleon I. But apart altogether from this particular phase of interest, Fontainebleau is a name that is constantly on the lips of glass manufacturers the world over, because of the fact that this particular district is renowned for its yield of beds of sand of the highest degree of purity yet discovered.

On arrival at Fontainebleau the party journeyed by motor cars for some eight or ten miles through the forest to the village of Saint Mammés, where there are situated some thirty-year-old sand quarries of M. Albert Bellefille, who is a large exporter of a quality of sand known as " Diamond-crystal." The firm possesses three large quarries capable of producing some 350 tons of sand per day. The cars were parked on the roadway whilst a visit was paid to one of the quarry faces in order to see exactly the geological formation of the sand-beds and the manner in which the sand is quarried or mined. It was shown how the better quality of sand lies beneath a stratum of second-grade sand, which has first to be removed or tunnelled under before the first quality sand can be worked. A private siding runs from the quarry to the railway station at Nemours, and also to a quay on the canal, from which point the sand can be conveyed by water direct to Rouen, there to be transferred to the Channel boats for despatch to England. The whole process was extremely interesting, particularly as M. Bellefille was himself present to give all the required information.

After motoring back to Fontainebleau, a luncheon, in honour of the visitors, was provided at the Hotel L'Aigle Noir. This was attended by numerous influential personages, including M. the Sub-Prefect of the Province, who presided and made a felicitous speech in proposing the health of " The Visitors." Prof. Turner, in returning thanks, mentioned that, from the point of view of the glass industry, Fontainebleau has long been renowned as one of the most important centres in Europe. The glass manufacturers

of England obtained all their best sand from this neighbourhood, and seeing that, in practically all glass, two-thirds of the total raw material used was sand, it was clear that Fontainebleau must necessarily rank as a very important source of the glass-maker's material. They would all take away with them very happy recollections of their visit to Fontainebleau, which had not only been extremely interesting, but most enjoyable from a social point of view.

A Crowded Day at Chantereine, Noyon, and St. Gobain.

The same evening the majority of the members of the party crossed over from the east to the north stations of Paris in order to spend the night at Compiegne, in readiness for an early start the next morning to an entirely new plate glass factory at Chantereine, a few miles distant. The whole of this new factory has been erected since the war on the most approved lines. On arrival at the works the visitors were given a *résumé* of the geographical situation and lay-out of the new factory, this being made clear by means of a large plan which was placed in the entrance hall. The gentlemen of the party were then conducted into the works, whilst the ladies, who were naturally rather more interested in the lay-out from a social and domestic point of view, were shown the welfare arrangements that have been provided for the workers.

The male members of the party, who were taken in hand by M. Delloye, M. Perrin, and M. Desbordes, were willingly shown all the details connected with the various processes of manufacture. An inspection was first made of the coal stores, and the methods adopted in the handling of the coal, which is received from the canal by means of an overhead steel ropeway. It was explained that, at first, the company experienced considerable difficulty in this connection, owing to the necessity of having to cross the Paris-Brussels main railway line, and they ultimately decided to instal this ropeway, which enables them to pass underneath the railway, since the Chemin de Fer du Nord would not give permission for them to pass above it. The coal arrives at the factory in small trucks, which are suspended from the ropeway, and these are discharged into an immense storehouse. From here the coal is taken, as required, to the gas producers.

At this stage the visitors were shown the mills for grinding the materials for the manufacture of the pots in which the glass is founded. From here the party entered the glasshouse, which is equipped with four melting furnaces and modern plant for handling
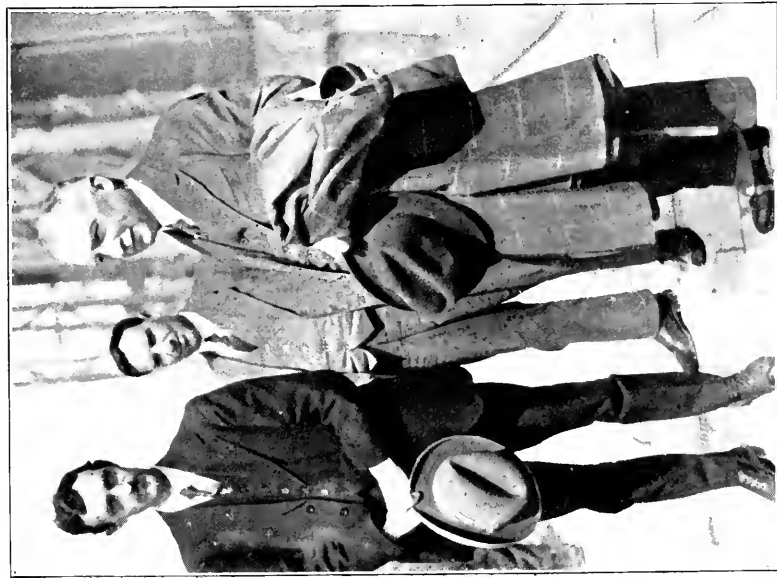
AT RHEIMS.

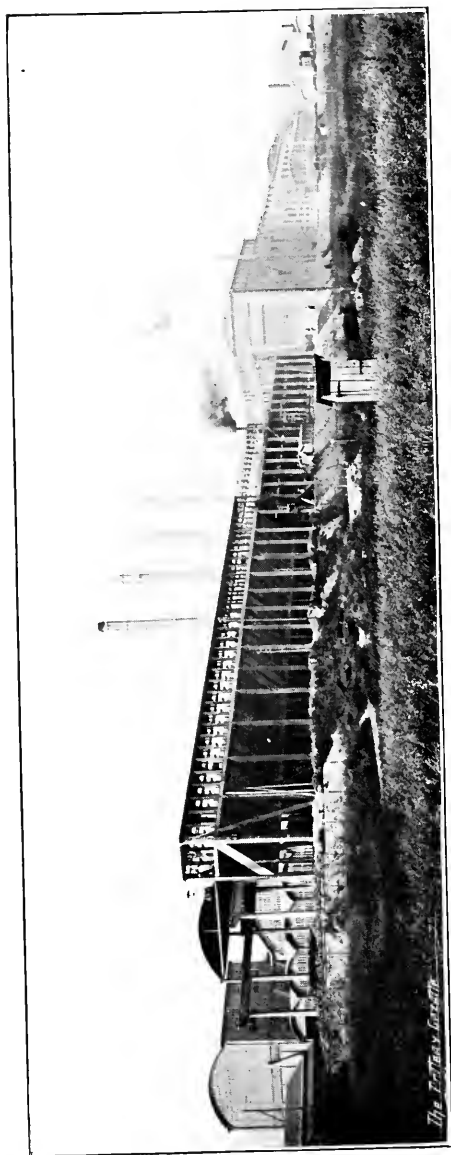THE PRESIDENT with M. CHARBONNEAUX.
(right.)
(left.)

AT NOYON.

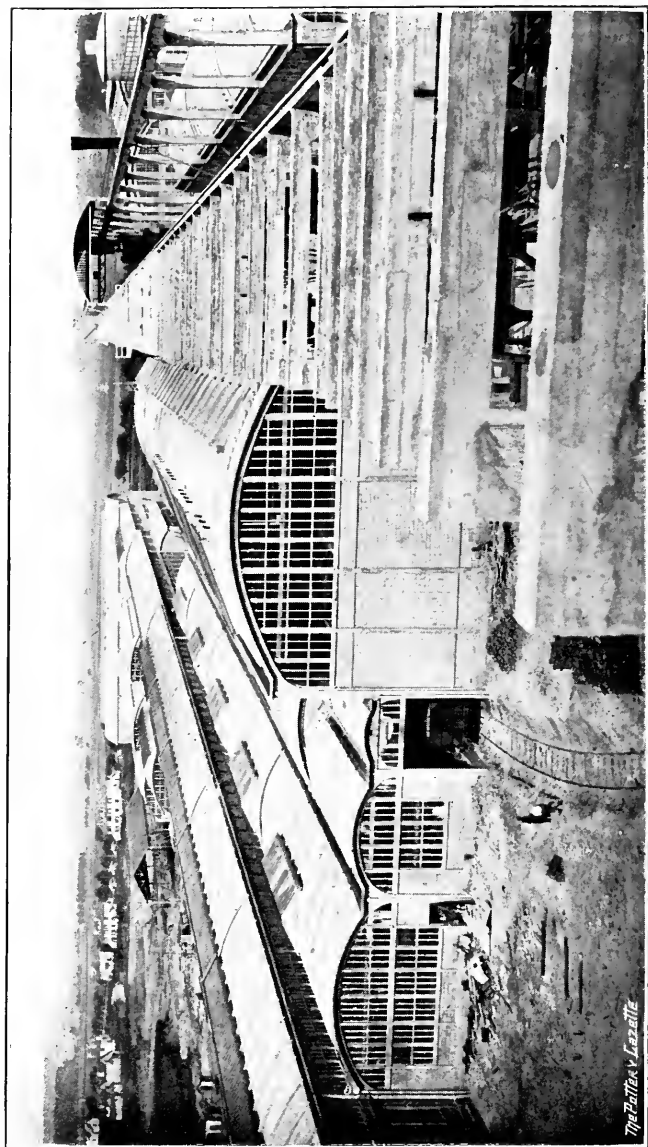M. BELLAYE with THE PRESIDENT.

A GROUP AT RHEIMS CATHEDRAL.

SOME OF THE PARTY AT NOYON.

NEW PLATE-GLASS WORKS AT CHANTEREINE.

The Patllex v. Lazaette

NEW PLATE-GLASS WORKS AT CHANTEREINE.

the pots, casting, rolling, and annealing. Casting operations were fortunately in progress just at the time of the visit.

The furnaces are gas-fired, from a set of concrete-walled producers. It was remarkable, indeed, to what extent concrete had entered into the construction both of the factory and of its equipment. The gas producers are of the Morgan type, having Chapman agitators and the Chapman system of coal filling. Each coal hopper is fitted with an indicator, which registers the weight of coal filled on.

The batch housing arrangements were next inspected. It was seen that the materials are stored in large ferro-concrete containers, out of which they are lifted by a special type of scoop and conveyed to hoppers above the batch-mixing machine. As each material is thrown into the hopper its weight is registered and recorded—a point worth specially noting. The materials then pass down into the batch mixer, and from there the mixed material is delivered into special bins, from which it is easily transported to the furnace.

The visitors were interested to note the control of the rate at which the lehrs are drawn. Each glass plate is assured of a definite time at a definite temperature. There is not only an electric recorded, but an electrically-propelled indicator.

When the glass plate is withdrawn from the lehr it is moved to and fro between the cutting tables, and from here into the warehouse, by means of large suckers, *i.e.*, rubber discs, which are placed on the plate and a vacuum applied.

The polishing tables were not for the time being in operation. Some of them were still under construction and, when completed, will be capable of dealing with plates of glass 34 feet square. The motors which operate the polishing tables are of 500 h.p.

This glassworks at Cantereine was by far the largest and most modernly-appointed of the factories that were visited during the tour, and the inspection of it was naturally much enjoyed by all who had the good fortune to share in it.

From Chantereine the journey was continued by motor cars to Noyon, where a halt was made at the Hotel Du Mont-Renaud for lunch, kindly provided by the directors of the glassworks of St. Gobain, Chauny, and Cirey. On this occasion—the last opportunity of the tour for any public announcements—M. Delloye intimated that the directors requested him to say that they were extremely pleased to see their guests, and they sincerely hoped that they would take back a happy remembrance of the few days that had been spent in association with the French glass manufacturers. Speaking, as he now did, at Noyon, which place was

well inside the fighting line, and had been almost obliterated from the map in consequence, he would like to say that if England were to support France in bringing Germany to the right point of view it would be to the interest of Germany herself, as well as to the interests of England, France, and the other Allies, for on every occasion when Germany felt that she was likely to get some support from England, Italy, or America, she immediately began to put up a fresh resistance, which was contrary to her own interests and to the rest of Europe. He would like to leave this thought with his English friends as his last word. He raised his glass to England, to France, and to the prosperity of the glass trade on both sides of the Channel.

Prof. W. E. S. Turner acknowledged the toast and said the occasion was one that provided them with the opportunity of expressing their hearty thanks and appreciation of all that had been done for them. He desired, on behalf of the members, to say how much they were indebted to M. Delloye, and also to his colleagues, M. Penir, M. Doisemaine, and M. Roy, for all their generous assistance both in making the tour possible and in making it pleasant. He said that he did not think that any amount of reading or thinking about the problem could have brought home to him what two or three days spent in the war area had succeeded in doing. He had now been made to understand what terrible havoc the Germans wrought in France during their invasion. He thought all who had taken part in the trip must realise and appreciate and feel ready to support what the French people were attempting to do, namely, to make the Germans pay for the wanton destruction which lay at their doors. Coming more directly to the glass industry, he could see no good reason why there should be anything in the nature of cut-throat competition between the English and the French manufacturers. Rightly directed, he believed there was plenty of work for both, and there were many ways in which they might help one another. Every country had its own contribution to make, and each had a right to make that contribution, and by coming together internationally in industry he thought something might be arranged to take the advantage of all. He was sure that if they cared to take advantage of an opportunity of discussing these questions further, M. Delloye would be found both ready and willing to give them the benefit of his well-informed views. He had been a charming guide and friend during the past few days, and apart altogether from what he had done to make the arrangements of the trip easy and comfortable, they had all been glad to have M. Delloye with them, for himself alone.

COL. S. C. HALSE supported, and expressed his delight at having been able that morning to see a factory which, to his mind, had been erected as the result of a combination of the best ideas, collected from various nations. It was a factory which had been started, as all good factories must be, in a green field. In England they were too much inclined to go on patching up the old stones, and refusing rigidly to scrap anything. After having had some experience of Government factories, he was disposed to think that it was not altogether an unmixed evil that the Germans had done a bit of scrapping for France, and if the present factory at Chantereine was to be taken as an illustration of how the new could replace the old, with a clean and fresh start, it might perhaps pay the English people to take a lesson from the scrapping methods of the Germans and do a bit of scrapping for themselves. He supported all that Prof. Turner had said in regard to their indebtedness to their hosts. From every point of view the trip had been a delightful experience and a real education.

On the last afternoon of the trip a visit was paid to the glass-works at St. Gobain, which were also well within the fighting line and occupied by the Germans. This factory, like many others, was badly damaged during the alternating losses and gains during the war. The St. Gobain works were originally a Royal factory in the reign of Louis XIV., and underneath the chateau the old dungeons can still be seen. It was a practice of the nobles in those days to visit the Royal glass works, order whatever objects they required, and spend the rest of the time hunting in the Royal preserves of the St. Gobain forest. The firm still exhibits a glass house pot that was made in the year 1825. This was taken away from the factory by the Germans during the war, but it was fortunately re-obtained from them through the instrumentality of the Reparations Commission and restored to the St. Gobain company. The oldest part of the chateau was destroyed entirely by the Germans during the war, and has since been rebuilt with many modern improvements.

The party returned to Paris the same evening, and made their way back to England in several separate contingents.

VISIT TO THE GLASS WORKS OF JAMES POWELL & SONS (WHITEFRIARS), LTD., WEALDSTONE

ABOUT sixty members of the Society of Glass Technology paid a visit to the newly erected Wealdstone works of James Powell and Sons (Whitefriars), Ltd., on the 17th May, and were conducted over the works by the manager.

A very close inspection was made of the new furnaces built for the company by Messrs. Dennis Simplex Furnaces, Ltd., These furnaces are of the recuperator type, and are fed from below with coal by the Frisbie feed mechanism, using a low grade coal. They have so far proved to be very efficient. Each furnace in use is fitted with recording optical pyrometers, giving a record of the temperature at one minute intervals, and for the convenience of the firemen indicators are fixed beside the furnaces to enable them to take the temperature while working. This plan of temperature recording has been found to be of great convenience, not only to the managers, who have a complete record of the temperatures to refer to, but also to the workmen, who can at any moment tell the condition of their fires.

The kilns, lehrs, and pot-arches used by the company are also fitted with pyrometers, and are fired from the same floor as the furnaces, and by the same men.

The visitors were shown the operation of spreading antique glass, which is very largely used by the Company in the manufacture of church windows.

A visit was also made to the tile-making department, where the firm's special form of art glass tile is produced.

The mixing shop, which was also inspected, consists of two separate departments, one devoted exclusively to the preparation of Whitefriars flint glass, used for cut glass- and table-ware, and the other to the preparation of soda glasses for chemical and other purposes.

The glasshouse itself is a large, roomy building containing two circular eight-pot furnaces. There is plenty of light and air, and great pains have been taken to ensure the comfort and convenience of the workmen employed.

Visits were made to the cutting shop, where cut glass table-ware

is produced. This shop is fitted with electric motors, and contains all the most modern apparatus for producing English cut glass.

The visitors were shown a number of examples of Powell's art productions as well as a quantity of finished glassware that was about to be dispatched to the retail premises at Wigmore Street, London.

At the conclusion of the visit a brief description of the works and the Company's activities was given by the manager, and a vote of thanks to the Directors was proposed by Prof. W. E. S. Turner, on behalf of the visitors, for the very instructive visit. Mr. J. H. Gardiner replied.

OBITUARY NOTICES.

EDWARD FERGUSON CHANCE, M.A.

MR. EDWARD FERGUSON CHANCE, who died at his residence, Sandford Park, Nr. Oxford, on May 20th, 1923, aged sixty-two, was the second son of Mr. Edward Chance, D.L., J.P., of Great Malvern, a brother of Sir James Timmins Chance and partner in the firm of Chance Brothers & Co. from 1853 to 1880.

After completing his education at Harrow and at Caius College, Cambridge, where he graduated in 1884, he came to work at the Alkali Works at Oldbury, and then at Spon Lane. He soon showed the value of his services, and in 1889, when the firm was converted into a limited liability company, was appointed a Managing Director. " Endowed " (to cite from Mr. J. F. Chance's history of the firm) " with extraordinary power of attention to detail, he was indefatigable in the pursuit of improvement." He was largely responsible for many important manufacturing developments, and possessed also a special aptitude for and ability in personal negotiations.

Mr. Chance was never of strong constitution, and when the war broke out in 1914 was already feeling the effects of his hard work and was intending to retire, but the exigencies of the time obliged him to continue, and even to increase his exertions, and the result, undoubtedly, was to shorten his life. Appointed Chairman of the Company in 1919, on the retirement of Mr. George Ferguson Chance, in 1921 the complete breakdown of his health, the consequence of overwork, obliged him to retire, to end his days under the watchful and loving care of his wife and family at home.

CHARLES JOSEPH BISHOP.

MR. C. J. BISHOP, head of the firm of Messrs. S. & C. Bishop & Co., and alderman of the Town Council of St. Helens, died on May 24th in his seventieth year. Mr. Bishop had had a life-long association with the glass industry, entering the well-known glass tube works at St. Helens while his father and uncle were still in the business. His interest and appreciation in the scientific aspect

of glass making were keen, and, in fact, he was amongst the very few older glass-makers in this country capable of understanding the chemical aspects and chemical calculations concerned with glass founding. In other respects, he was a well-read and well-travelled man, both business and pleasure having taken him to many countries.

In regard to public work Mr. Bishop had an exceedingly long record of more than forty-four years' service in St. Helens, and had served on practically every Committee of the Corporation, in particular as Chairman of the Highways Department, Chairman of the Education Committee, and Deputy Chairman of the Parliamentary Committee. Twice also he had filled the most important office in the borough, namely, that of Mayor. Alderman Bishop was a J.P. both for the borough of St. Helens and for the county of Lancaster, and his passing has meant the removal of a noteworthy figure in the public life of St. Helens and an intelligent and efficient member of the glass industry.

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PROCEEDINGS OF THE SIXTY-FOURTH MEETING.

HELD in the Applied Science Department, The University, St. George's Square, Sheffield, on Wednesday, October 17th, 1923, at 3.0 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the Chair.

A cordial welcome to the meeting was given to Sir W. Henry Hadow, C.B.E., M.A., D.Mus., Vice-Chancellor of the University of Sheffield, and to Prof. W. Rothenstein, M.A., Principal of the Royal College of Art, London, and Professor of Civic Art in the University of Sheffield, who attended in connection with the presentation of " Frank Wood " medals.

Before presenting these medals to the successful students, Sir HENRY HADOW said he felt sure they would not expect an oration, especially as they had on the agenda some remarkable and interesting papers for discussion. It was a very great pleasure for him to be there that afternoon and to take part in a very enjoyable ceremony, and particularly, after what their President had said, to do so in the presence of Prof. Rothenstein, to whom they were ultimately indebted for the work which had been put into the beautiful medal through a student of his college. It was very seldom one got any artistic design applied to the industry, as appeared on these medals.

They were very glad of the Department of Glass Technology, because it enabled them to count among their members Prof. Turner, and he really thought it was a feather in the University's cap, as it stood out among the Universities of this and other countries in applying its scientific help and service to a great and important industry like glass. It had, as they knew, been going through deep waters during the last few years, but most of the industries had been hit hard since the war, and the glass industry certainly not less than other industries, and the University had had to bear some part of this. On that point he quite recognised the difficulties they had been going through. He had attended some of the business and so-called financial meetings of the Delegacy. He was quite sure, however, that things were coming right, and in the course of time they would pull through, and the Department would flourish as it ought to do.

A great deal of help was given to them in their work and to their appeals by such a Society as theirs. He was very pleased indeed to see it meeting there that afternoon.

Amongst the greatest supporters of the glass work which the

University had in that district there was no one whom they honoured more than Mr. Frank Wood, and it was entirely appropriate that the medals they were awarding that afternoon should bear his name.

He would just like to say a word or two about the two successful students who had won these medals. One, Mr. F. Winks, had taken up a post as Student Research Assistant in the Department of Glass Technology of Sheffield University, and he would like to congratulate him on that appointment and hoped it would lead him to success in the future. To the other student, Mr. A. R. Sheen, they were especially grateful for having done good service in more than one sphere, not only as an enthusiast of glass, but also as a participant in University athletics, and he believed also in University music.

Sir HENRY HADOW then presented the medals to the two successful students, Arthur Renwick Sheen, B.Sc.Tech., and Francis Winks, B.Sc.Tech.

The PRESIDENT observed that the design of the " Frank Wood " medal was the work of Mr. Percy Metcalfe, a former pupil of Prof. Rothenstein's. The latter, at the request of Prof. Turner, then addressed the meeting.

Prof. Rothenstein remarked that he would just like to say one thing with regard to the medal, namely, that it had been the custom during the last century when medals were required, to go to France for them, but whenever an Englishman got his chance he showed how much better he could do the work than anyone else. He had a sense of power which one found all true British had, but for some reason or other people would not realise that to have faith in their own contemporaries was one of the first duties of citizenship. He hoped that those who were going to want medals in the future would remember when any work of this kind was to be done that there were those in this country who could do it. He hoped they would take it from him that good medals were always the rarest form of art, and the Society's particular medal would have its place in history. He desired to congratulate the winners, not only for the fine tribute to their own work the medals represented, but also in being able to hand them on as heirlooms representing the best craftsmanship of their day.

On the motion of Col. S. C. HALSE, seconded by Mr. W. BUTTERWORTH, a cordial vote of thanks was accorded to Sir Henry Hadow and Prof. Rothenstein for their attendance at the meeting. Sir Henry Hadow replied.

The death was recorded with regret of Mr. P. C. Whittaker, managing director of Messrs. W. Nelson, Ltd., Manchester.

The PRESIDENT gave a short report of the visit to France during the first week of July. He said that those members who took part in the visit had expressed their warm appreciation of the hospitality and welcome which they had received.

On the motion of the PRESIDENT, seconded by Col. S. C. HALSE, a recommendation from the Council was unanimously adopted, namely,

> " That a cordial invitation be sent to our members in France, and conjointly to the Chambre Syndicale des Maîtres de Verreries, to meet us in conference in this country, some time during the year 1924."

A vote of Thanks was accorded to Messrs. Vickers, Ltd., for their courtesy in permitting a party of members to visit their River Don Works, Sheffield, during the morning.

A paper entitled " The Effect of Titania on the Properties of Glass," by A. R. SHEEN, B.Sc.Tech., and Prof. W. E. S. TURNER, D.Sc., was presented by the former and illustrated by lantern slides. Mr. Sheen's remarks were supplemented by Prof. Turner, after which a discussion took place, those contributing being Messrs. W. J. Rees, S. English, Donald Robertson, W. F. Pearson, and W. Butterworth. Prof. Turner replied.

Mr. A. COUSEN, B.Sc., A.R.C.S., presented a paper entitled, " The Estimation of Selenium in Glass." This paper was illustrated by experiments and elicited a discussion in which there took part the President, Messrs. W. J. Rees, J. H. Davidson, and J. R. Clarke. Mr. Cousen replied.

Votes of thanks were accorded to the authors of the papers presented to the meeting.

Opportunities for social intercourse were afforded when members met together for lunch before the meeting and at tea afterwards.

The following were elected Ordinary Members :—

Elbridge J. Casselman, S.B.	*Chemical Engineer*, Mellon Institute of Industrial Research, Pittsburgh, Pa., U.S.A.
Max Henry Cornaz.	*Electro-Chemical Engineer*, Verreries de St. Prex, and Glashütte, Bülach, Switzerland.
Mrs. May Badger Craven, M.Sc.Tech.	*Assistant Lecturer in Chemistry*, College of Technology, Manchester.
Pau Cheng King, B.S.	*Engineer*, The Yao Hera Mechanical Glass Co., Chinwangto, China.
Jean Maillart.	*Chemical Engineer*, 3, rue de Castellane, Paris.

Alfred Oppenheimer.

Glass Bottle Merchant, 14, Queen Victoria
Street, London, E.C. 4.

Frederick Jobbé-Duval.

Engineer, Managing Director, Bouteilleries
de Lommel.

Samuel Peacock.

Director, Suite 405, Wheeling Steel Cor-
poration Building, Wheeling, W.Va.,
U.S.A.

PROCEEDINGS OF THE SIXTY-FIFTH MEETING.

HELD in the Lecture Room of the Department of Coal Gas and Fuel Industries, the University, Leeds, on Wednesday, November 21st, 1923, at 2.30 p.m., the President, PROF. W. E. S. TURNER, D.Sc., in the Chair.

The PRESIDENT directed attention to the Roll of Members and the Suggestion Book, both of which were passed round during the meeting.

A vote of thanks was accorded to Messrs. Leeds Fireclay Co., Ltd., for their courtesy in permitting a party of members to visit their Wortley works during the morning.

A vote of thanks was also accorded to the authorities of the University of Leeds and to Prof. J. W. Cobb for their courtesy in providing accommodation for the meeting of the Society.

A paper entitled " Note on the Influence of Rapid Chilling on the Reversible Expansion of Clay " was presented by H. S. HOULDS-WORTH, M.Sc., and illustrated by lantern slides. To the discussion that followed there contributed the President, Messrs. E. A. Coad-Pryor, T. Teisen, and H. J. Hodsman. Mr. Houldsworth replied.

A paper, illustrated by lantern slides, was presented by Prof. KURD ENDELL, Dr. Phil., of Berlin. This paper was entitled " The Casting Process for Glasshouse Refractories in German Glass Plants." It elicited a discussion in which there took part the President, Messrs. G. V. Evers, J. Connolly, E. A. Coad-Pryor, J. H. Davidson, A. Bonson, T. Teisen, and H. J. Hodsman. Prof. Endell replied.

A paper entitled " Glasshouse Pots : Some Notes on their Manufacture and Use," by PERCIVAL MARSON, was read by the President in the absence of the author. A discussion followed to which there contributed the President, Messrs. F. G. Clark, G. V. Evers, and E. A. Coad-Pryor.

Votes of thanks were accorded to the authors of the papers presented to the meeting.

The following were elected Ordinary Members :—

Walter Biheller.   *Manager*, Messrs. Weiss, Biheller & Brooks, Ltd., 71, Chiswell Street, London, E.C. 2.

Charles William Death.

Works Clerk, Messrs. Crystal Glass Ltd., Wyndham Street, Alexandria, Sydney, N.S.W., Australia.

Neville Bensley Mattingley.

Technical Chemist, Messrs. Automatic Bottle Makers, Ltd., Trafford Park, Manchester.

F. L. Steinhoff, B.Sc.

Editor, " Ceramic Industry," 407, South Dearborn Street, Chicago, Illinois, U.S.A.

Adolph Henry Charles Wenger.

Managing Director, Messrs. Wengers Ltd., Etruria, Stoke-on-Trent.

PROCEEDINGS OF THE SIXTY-SIXTH MEETING.

HELD in University College, Gower Street, London, W.C. 1., on Wednesday, December 12th, 1923, at 2.30 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the Chair.

A vote of thanks was accorded to the authorities of University College, London, for their courtesy in providing accommodation for the Society's meeting, and in allowing members to use the College Refectory.

A paper entitled " An Apparatus for the Calibration of Burette Tubes " was presented by VERNEY STOTT, B.A., F.Inst.P. To the discussion that followed there contributed Messrs. S. English and F. F. S. Bryson.

Mr. ERIC FARMER, M.A., of the Industrial Fatigue Research Board, gave a paper entitled " Some Factors Affecting Efficiency in the Glass Trade." This paper was illustrated by lantern slides, and elicited a discussion in which there took part the President, Messrs. S. English, F. F. S. Bryson, A. Stevenson, E. A. Coad-Pryor, G. V. Evers, Ed. Meigh, D. R. Wilson, and Col. S. C. Halse.

The last paper on the Agenda, namely, " Specifications in the Glass Industry, with Special Reference to Soda-Lime Glasses for Containers," was presented by the President, Prof. W. E. S. TURNER, D.Sc., F.Inst.P., and was followed by a discussion to which there contributed Col. S. C. Halse, Messrs. E. A. Coad-Pryor, F. F. S. Bryson, F. W. Adams, and Ed. Meigh.

Votes of thanks were accorded to the authors of the papers presented to the meeting.

The following were elected ordinary members :—

Masanochi Nakatsuji.	*Engineer in Ceramics*, The Shoseikan Crucible Manufacturing Co., Ltd., Gamo Joto, Near Osaka, Japan.
James Belcher.	*Warehouse Foreman*, Messrs. John Lumb & Co., Ltd., Castleford.
Herbert Townsend.	*Assistant to Glass Maker*, Messrs. John Lumb & Co., Ltd., Castleford.

The PRESIDENT stated that the second and third of these applicants came in under the recently approved scheme applicable to manual and clerical workers in the industry. They had received great encouragement to make application from Col. S. C. Halse, of Messrs. John Lumb & Co., Ltd., and he (the President) trusted other manufacturers would follow the lead thus set.

VISIT TO THE RIVER DON WORKS, SHEFFIELD, OF MESSRS. VICKERS, LTD.

DURING the forenoon of Wednesday, October 17th, 1923, a party of more than twenty members of the Society had an opportunity of visiting the River Don Works of Messrs. Vickers, Ltd. In the rolling mill, special tool steel was being passed through a series of rollers whereby an ingot about 15 inches square and 6 feet long was gradually converted into a bar some 3 inches square and 150 feet long. It was then cut up into lengths. In the crank shop, the various processes in the turning of shafts, large and small, were in operation. In another shop, tyres were being forged and rolled. The party was specially interested in the large battery of Duff producers, and appreciated the explanations given by Mr. J. Imrie, the manager of the department. The party was then conducted to another battery of producers, here of the Rehman type, used in connection with the melting furnaces. These producers were fitted with mechanical ash removers.

Messrs. Vickers, Ltd., have three works in Sheffield, with a total area of 94 acres. The River Don Works cover 83 acres and have five thousand employees. The main products are armour plate, guns, and all kinds of armament material, tool steel, rolled bars and billets, forgings of all kinds of sizes up to 130 tons each, steel castings, drop stampings, railway tyres, springs (laminated and spiral), steel pressings for motor-cars and other road vehicles, files, hack-saws, oil-well boring tools, cold-drawn steel tubes, steel sheets, and electric motors and generators.

OBITUARY NOTICES.

WE regret to record the deaths of :

Mr. KLAS ÖSTLUND on February 5th, 1922. Mr. Östlund, who was one of the first of our members in Sweden, being elected in April, 1919, entered the firm of Arvid Böhlmark in 1877 and after the death of his uncle, the founder of the firm, became its head in 1897. In that year the firm was transformed into a limited liability company, the Aktiebolaget Arvid Böhlmarks Lampfabrik, and Mr. Östlund remained as its manager until his death.

Mr. PERCY COOPER WHITTAKER, Chairman and Managing Director of Messrs. Wm. Nelson, Ltd., Ancoats Glass Works, Manchester, died, after a very painful illness, on August 28th last.

Mr. Whittaker, who was born in 1872, began his career with Messrs. Armstrong, Whitworth & Co., Ltd., at Openshaw, and remained in their foundry department until 1900, when he set up a foundry business of his own. In 1905 he purchased, with others, the glass works of his father-in-law, Mr. William Nelson, and became and remained Chairman and Managing Director of the company until his death. He was a keen rotarian and a great sportsman, having won many prizes on the track and on the road as an amateur cyclist between 1890 and 1897, whilst in later years he became a very proficient golfer.

TRANSACTIONS

LIST OF ABBREVIATIONS EMPLOYED IN THE JOURNAL.

ABBREVIATED TITLE.	JOURNAL.
Amer. J. Sci.	American Journal of Science.
Analyst	The Analyst.
Ann. Physik	Annalen der Physik.
Ann. Physique	Annales de Physique.
Ber.	Berichte der Deutschen chemischen Gesellschaft.
Ber. Deut. physikal. Ges.	Berichte der Deutschen physikalischen Gesellschaft.
Brit. Clayworker	British Clayworker.
Bull. Soc. d'encouragement pour l'Ind. Nat.	Bulletin de la Société d'encouragement pour l'Industrie Nationale.
Bull. Geol. Soc. America	Bulletin of the Geological Society of America.
Chal. et Ind.	Chaleur et Industrie.
Chem. Met. Eng.	Chemical and Metallurgical Engineering.
Chem. News	Chemical News.
Chem. Zeitung	Chemiker Zeitung.
Chim. et Ind.	Chimie et Industrie.
Compt. rend.	Comptes rendus hebdomadaires des Séances de l'Académie des Sciences.
Deut. Mech. Zeitung	Deutsche Mechaniker-Zeitung.
Elektrotech. Zeitsch.	Elektrotechnische Zeitschrift.
Gas J.	Gas Journal.
Gas World	Gas World.
Geol. Mag.	Geological Magazine.
Glashütte	Die Glashütte.
Glasindustrie	Die Glasindustrie.
Glass Container	Glass Container.
Glass Ind.	Glass Industry.
Illum. Eng.	Illuminating Engineer.
Iron Age	Iron Age.
J. Amer. Cer. Soc.	Journal of the American Ceramic Society.
J. Amer. Cer. Soc. (Bull.)	Bulletin of the American Ceramic Society.
J. Amer. Chem. Soc.	Journal of the American Chemical Society.
J. Chem. Soc.	Journal of the Chemical Society.
J. Franklin Inst.	Journal of the Franklin Institute.
J. Inst. Metals	Journal of the Institute of Metals.
J. Geol.	Journal of Geology.
J. Ind. Eng. Chem.	Journal of Industrial and Engineering Chemistry.
J. Iron Steel Instit.	Journal of the Iron and Steel Institute.
J. Opt. Soc. Amer.	Journal of the Optical Society of America.
J. Physical Chem.	Journal of Physical Chemistry.
J. pr. Chem.	Journall für praktische Chemie.
J. Russ. Phys. Chem. Soc.	Journal of the Physical and Chemical Society of Russia.
J. Soc. Chem. Ind.	Journal of the Society of Chemical Industry.
J. Washington Acad. Sci.	Journal of the Washington Academy of Sciences.
Ker. Rundschau	Keramische Rundschau.
Kolloid-Zeitsch.	Kolloid-Zeitschrift.
Le Verre	Le Verre
Mon. Scient.	Moniteur Scientifique.
Nat. Glass Budget.	National Glass Budget.
Optician	The Optician and Scientific Instrument Maker.
Phil. Mag.	Philosophical Magazine.
Phil. Trans.	Philosophical Transactions of the Royal Society of London.
Phys. Review	Physical Review.
Physikal. Zeitsch.	Physikalische Zeitschrift.
Proc. Inst. Chem.	Proceedings of the Institute of Chemistry.
Proc. K. Akad Weten. (Amst.)	Proceedings, K. Akad van Wetenschappen, Amsterdam (English Version).
Proc. Phys. Soc.	Proceedings of the Physical Society of London.
Proc. Roy. Soc.	Proceedings of the Royal Society.
Quart. J. Geol. Soc.	Quarterly Journal of the Geological Society.
Rev. d'Optique	Revue d'Optique.
Sprechsaal	Sprechsaal.
Stahl u. Eisen	Stahl und Eisen.
Tonind. Zeit.	Tonindustrie-Zeitung.
Trans. Amer. Cer. Soc.	Transactions of the American Ceramic Society.
Trans. Amer. Illum. Eng. Soc.	Transactions of the American Illuminating Engineers' Society.
Trans. Cer. Soc.	Transactions of the Ceramic Society.
Trans. Farad. Soc.	Transactions of the Faraday Society.
Trans. Optical Soc.	Transactions of the Optical Society.
Zeitsch. analyt. Chem.	Zeitschrift für analytische Chemie.
Zeitsch. angew. Chem.	Zeitschrift für angewandte Chemie.
Zeitsch. anorg. Chem.	Zeitschrift für anorganische Chemie.
Zeitsch. Elektrochem.	Zeitchrift für Elektrochemie.
Zeitsch. Instrumentenkunde	Zeitschrift für Instrumentenkunde.
Zeitsch. physikal. Chem.	Zeitschrift für physikalische Chemie, Stöchiometrie und Verwandtschaftslehre.

S K . . . . Seger Cone.
All temperatures are expressed on the Centigrade scale.

I.—*Improvements in the Design of Recuperative Glass Pot Furnaces.*

By Th. Teisen, B.Sc.

(*Read at the London Meeting, December 13th, 1922.*)

In March 1917 I had the privilege of reading a paper in Birmingham before the Society on the developments of glass furnaces on the Continent, and on the various types used.

The present paper will deal with such improvements as have taken place since then, more particularly with the furnaces which have recently been built in this country to the author's design and patents. Before going into the design of the furnace itself, I should just like to mention briefly a few points not referred to in my previous paper relating to recuperators of the "Hermansen" type. In the author's view, these recuperators possess certain advantages not shared by other systems on the market—for instance, the Radot-Lencauchez type with vertical air channels *—and apparently overlooked in the claims made for the same.

One of the advantages is the increased security against leakage obtained by the crosswise arrangement of air channels in relation to the waste gas channels as well as the interlocking principle on which the tubes are made. It will be seen that to establish a leak the direction which an air or gas current has to take to enter respectively the waste gas or air channels will have to be broken at least four times, or, to put it more simply, it has to pass four joints filled with clay, of which one good joint alone is sufficient to stop the leakage. This gives a great safety margin as compared with other types where a short-circuit usually may take place without breaking the direction or joints more than twice.

Another advantage is the possibility of increasing or decreasing the area of the waste gas or secondary air flues according to choice, allowing for a constant speed of the moving gases, particularly of the air. To work a recuperator with the highest efficiency it is necessary to have the air and gas passing through it at a fairly

* A description of this recuperator is given in "La Verrerie au XXe. Siècle," by Jules Henrivaux, page 61.

constant speed. If the speed be increased the resistance is also increased and this in the case of the secondary air means loss of positive pressure in the pot chamber, while in the case of the waste gas the whole recuperator will work under a greater reduction of pressure than is good for fireclay construction.

On the other hand, if the speed is unduly low the efficiency is decreased on account of the air and gas films adhering to the walls of the recuperator retarding the transfer of the heat from the moving waste gases to the secondary air through the tube wall and the gas film on either side. It is therefore necessary to make a compromise; that is, to select a moderate speed for either air or waste gas which, on the one hand, does not give too high a vacuum and on the other reduces the thickness of these gas films to a degree which makes their influence of little or of no importance. The speed of the air and gas need not necessarily be the same, and depends entirely on the design of the recuperator. What is necessary only is that the average speed selected in each case shall not be unduly increased or decreased during the passage through the recuperative channels.

As the air and gases expand about four and a half times between normal temperature and 1000°, it will readily be understood that, in order to keep a constant speed through the recuperator, the area must be increased in proportion. This is easily obtained in this type of recuperator by arranging several rows of passages parallel. The waste gases on entering the top rows of recuperator tubes are allowed a greater area there than in the bottom ones where the temperature is lower, and *vice versa*, the cold secondary air on entering the air channels in the bottom may only have one row of channels through which to pass, but may have two, three or four at each successive turn as it goes higher up in the recuperator.

It is evident that when the speed is kept in check at a moderate figure as defined above, the loss of positive pressure by friction and change of direction can be made a negligible quantity resulting in ample positive pressure in the pot chamber above, and this is confirmed in practice by the ease with which an open pot furnace can be worked with this type of recuperator.

I shall now go over to the main part of this paper relating to the design of the furnace proper as apart from the recuperators. Here, rather great developments have taken place since the description given in 1917. Before the war, when material and labour were comparatively cheap, the life of the furnace did not matter so much as now. Great saving in fuel had already been obtained by the introduction of this and other producer gas-fired recuperative types, and although further improvements have been made towards

reducing the fuel consumption, the tendency has been mainly concentrated on making the design more safe, with the view of giving it a longer life, and generally making the furnace more trustworthy and foolproof. The use of machinery, which has come to the front during recent years, has had a stimulating influence in this direction, since an idle furnace now represents a much greater loss of money on account of the expensive machines which are kept unproductive during a standstill for furnace repairs.

Further, the furnace units have been considerably increased in capacity, and while before the war a furnace with, say, 8 pots of 10-cwt. each was considered a large size, new ones having 8—12 pots of the American 3000-lb. standard size are already now working successfully in leading British works.

A general complaint against the gas-fired furnace, either regenerative or recuperative, has been the leakage of molten glass through the brickwork, penetrating into and damaging the vulnerable parts such as the regenerators and recuperators below the siege, and to prevent this two different methods have been employed. One consists in placing the regenerator or recuperator outside the furnace altogether; the other in isolating these parts in an efficient and safe manner.

In the first case, it can be seen that unless the heat recovery section is placed quite a distance from the furnace this method is not absolutely safe, whilst, if this condition is not maintained, it gives the furnace a larger surface, and as the losses by radiation and convection in a furnace are already considerable, amounting to about one-third of the total fuel consumption, it is not the most ideal manner.

The other method of isolating the recuperator gives a compact furnace with the smallest possible surface, consequently giving greatest heat economy. This is the method the author has adopted in his new designs, and as an example diagrams are shown (Figs. 1 and 2) of a 10-pot recuperative glass-melting furnace * erected for the Lemington Glass Works near Newcastle.

This furnace is fired in two step-grate producers arranged centrally in the furnace and flanked on either side by a recuperator as usual. The gas from the producer enters a central burner, beneath which is arranged a pocket where the glass from a broken pot will run. The glass pocket is of special design. It is of rather large capacity, to allow a considerable quantity of spilt molten metal to stand over during melting, so as not to upset the other pots of

* Designed under Hermansen Patent 15887/15; Teisen Patent 183394/21; Teisen Prov. Patent Appl. 34544/21; for Messrs. Lemington Glassworks, Lemington-on-Tyne.

glass undergoing refining.   Means for heating the glass pocket are
provided, a matter of special importance where the furnace gas is
rather cold or where the glass made is hard and easily freezes.

It will be seen on the drawing that a draw-off flue (10) is arranged
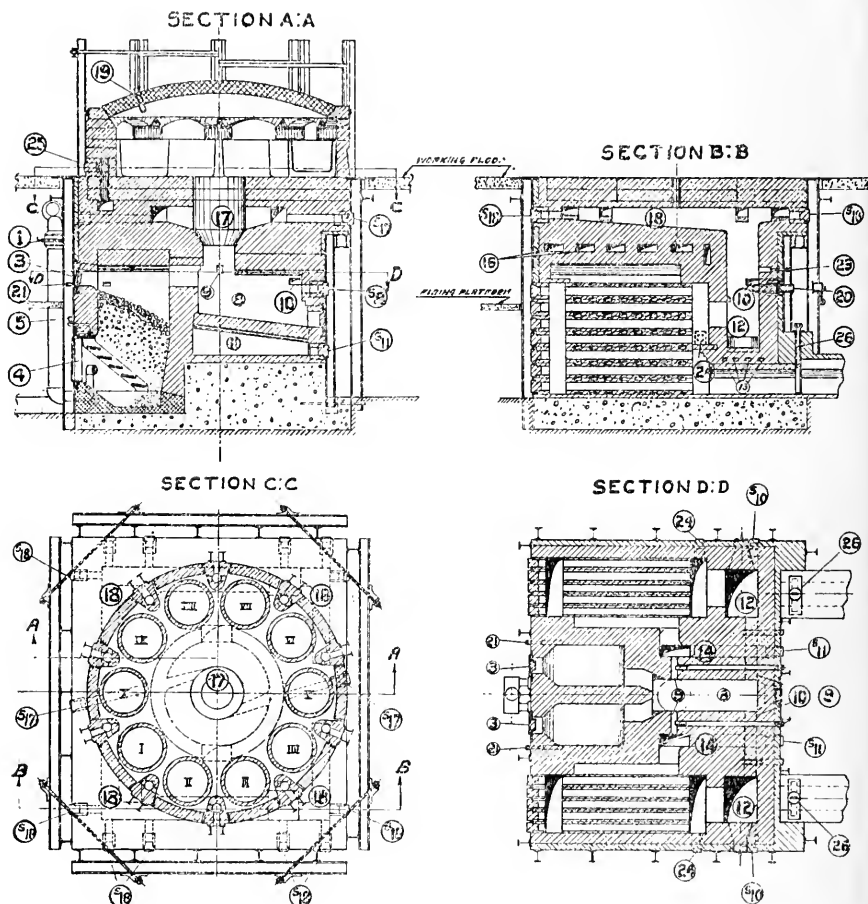at the end of the pocket leading the waste gas direct to the

Fig. 1.

recuperator.   Under ordinary working, this is closed.   The bottom
of the glass pocket consists of arches or blocks with an air space
below, which allows for cooling as required.   This arrangement makes
the repair of the pocket an easy matter, and any leakage of glass
from the pocket is limited to that flowing through the side wall to
places where, as will be seen later, it can be easily trapped.   In

older designs the bottom was solid and the glass in time penetrated the brickwork, which in due course gave way, resulting in the sinking of parts of the furnace, penetration of glass into the flues and filling them up. All this has now been successfully overcome.

A special feature of the furnace is the tangential burner.* It is a well-known fact that where direct-fired furnaces are replaced by the most efficient gas furnaces, working with either regeneration

SIDE ELEVATION

BACK ELEVATION

FRONT ELEVATION

DESCRIPTION.

1. Primary air slide for blast.
2. Primary air slide for natural draught.
3. Producer fire doors.
4. Producer ash doors.
5. Water inlet pipes for step grate.
6. Overflow pipes.
7. Secondary air slide.
8. Main glass pocket with door No. 14, 15.
9. Auxiliary air inlet for burner and main glass pocket.
10. Auxiliary waste gas outlet from main glass pocket.
11. Hollow space below main glass pocket (safety pocket).
12. Side glass pocket with door No. 65, 66.
13. Cooling channels under side glass pocket.
14. Secondary air pocket.
15. Trapping flues below secondary air pocket.
16. Cooling channels above recuperators.
17. Tangential burner.
18. Waste gas flues.
   Pots numbered I to X.
19-20. Pyrometer in top and base.
21-23. Gas analysis pipes in producer, before and after recuperator.
24. Inspection stopper for rec. division.
25. Inspection stopper for downtake flue in pillar.
   All other stoppers are marked "S" with index No. referring to respective ref. No. of flues, etc., for which stoppers are provided.
26. Furnace dampers.

FIG. 2.

or recuperation of the secondary air, the higher flame temperatures have often resulted in damage both to the siege blocks round the outlet of the burner as well as to the pots. The sudden combustion which takes place in a vertical burner with radial air inlets gives admittedly a very high local flame temperature which requires the highest quality siege blocks and pots to withstand it, unless the flame temperature is reduced artificially by decreasing or increasing the amount of secondary air unduly, which, of course, does not agree with economical working. Various attempts have

* This has been patented by the author.

been made from time to time to overcome this trouble, and different
theories brought into bearing to support them, but, unfortunately,
the expectations raised have not been realised in practice.

In the author's new burner, the secondary air is admitted tan-
gentially to the burner and is caused to swirl round the gas stream,
the latter entering from below and occupying the central portion
of the burner.   The combustion starts where the two streams meet,
but between this preliminary region of combustion and the surface
of the burner there is a lining of air which serves to protect the
surface from the destructive action of the flame.   The final mixing
of the gas and air and the completion of combustion occurs first
when the gases emerge from the burner, resulting in a more uniform
and widespread distribution of the temperature than is otherwise
obtainable.

This burner arrangement is indicated in section CC. (Fig. 1) in
which the tangential air inlets are dotted in.   These latter can be
inspected from the outside by removing the plugs (S.17).

The theory of this burner is very simple, and when designed
correctly has already in practice given good results.   Whereas, for
instance, in older designs, the edge of the burner was usually
destroyed in a month or two, a large 12-pot furnace recently built
and supplied with this new type of burner has been running for
about twelve months at an actual temperature of between 1400°
and 1500° and the edge round the burner is still perfect, in spite
of the fact that the furnace has most of the time been worked with
a secondary air supply of only 20—25 per cent. of excess air, giving
the highest thermal efficiency obtainable in practice.

Similar instances could be quoted from other works, and this
burner has, therefore, already shown in practice its value to furnaces
of this or similar types.

The illustration (Fig. 3) shows the latest arrangement of this
burner as applied to a large 8-pot furnace under erection for
Messrs. B.T.H. new glass works at Chesterfield.

The waste gases from the pot chamber are led away in the usual
manner through holes provided in the pillars and arranged in front
of the pots, from where they are distributed to two connecting
waste gas channels (18), which end in the side glass pockets (12)
before the waste gas finally enters the recuperator.   In these
pockets, the glass which may penetrate the joints of the siege or
pillars finds its way down and is taken out through doors at the
side, before it flows over the bridges provided and reaches the
recuperators.

Another feature of this furnace is, as mentioned before, the
means for protecting the recuperators and other vulnerable parts

Fig. 3.—Tangential Burner (Teisen's Patent); 8-pot furnace, B T.H., Chesterfield.
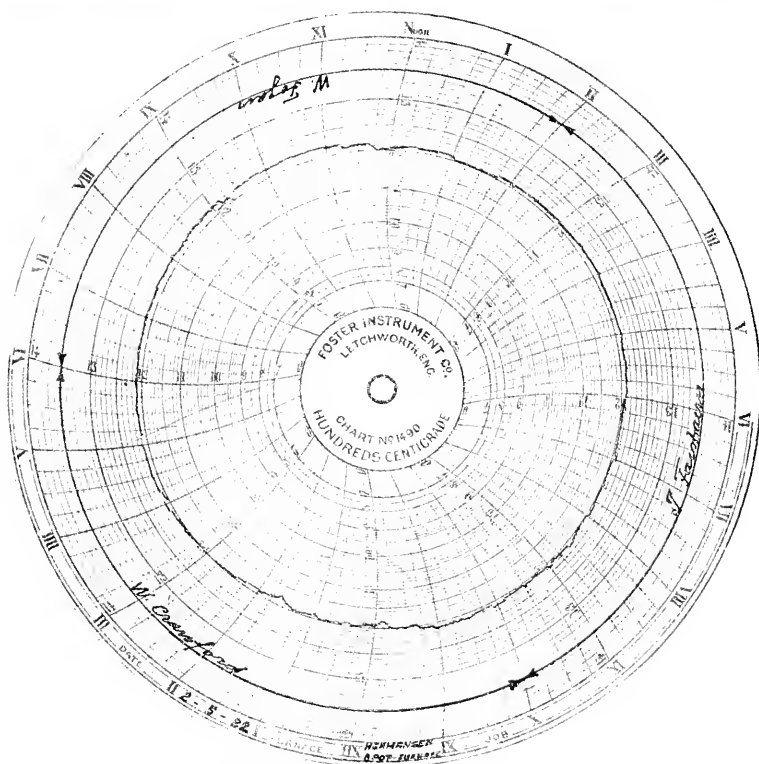
Fig. 5 —Temperature Chart. New 8-pot furnace; Edinburgh.
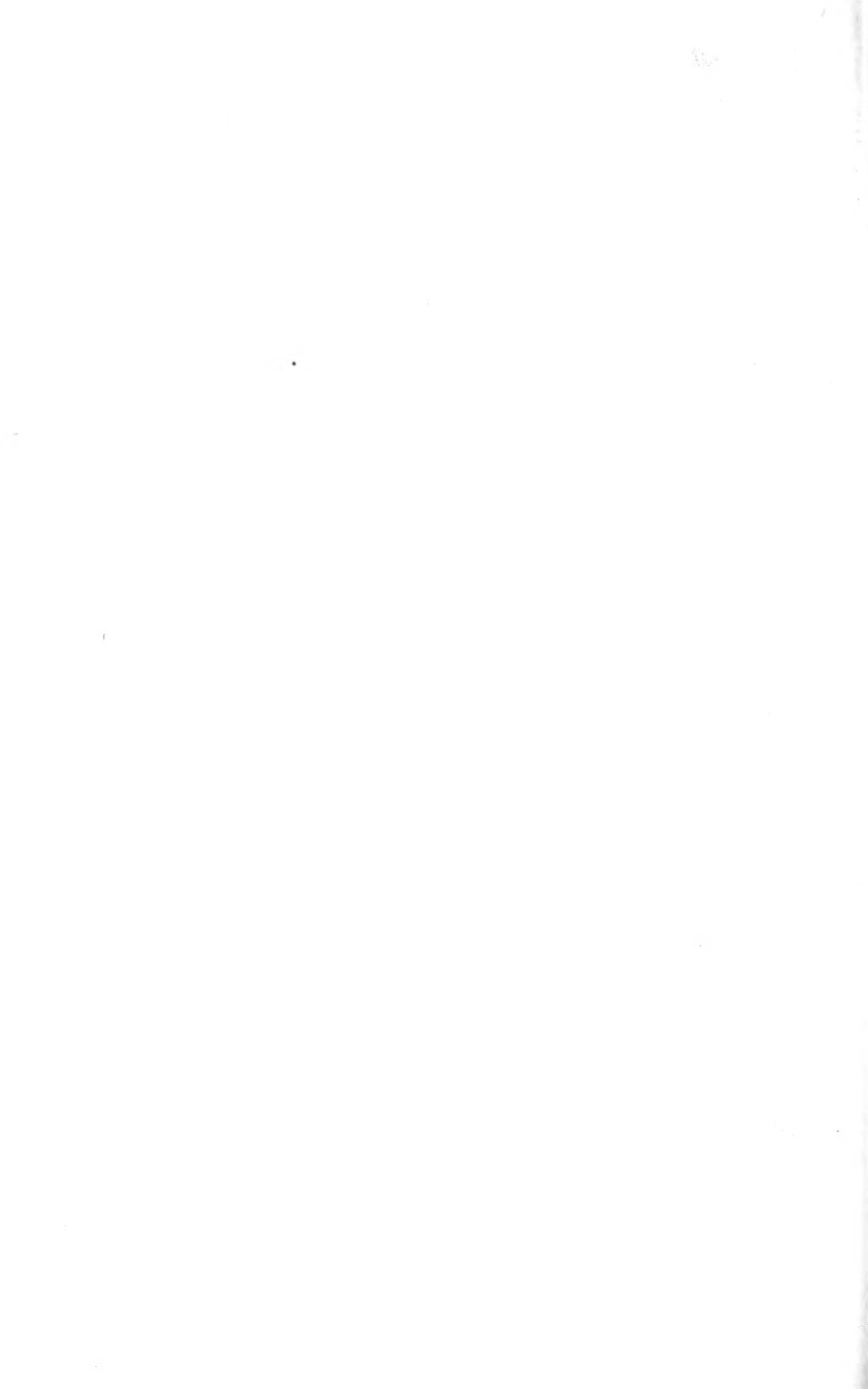
below from any flow of glass from the siege or from the central glass pocket. For this purpose, a number of horizontal cooling channels (16), through which a certain controllable amount of cold air passes by natural draught, are arranged over the recuperators, and these project sufficiently far into the surrounding brickwork so as to stop effectively any molten glass from penetrating the arches over the recuperators, particularly the parts near the skewbacks.

At the side of the recuperators, between these on the one side and the central waste glass pocket on the other, are arranged special trap pockets or flues (14) which prevent glass from reaching the recuperator through the intermediate brickwork.

These pockets are divided into an upper pocket formed in the secondary air flue, in which molten glass flowing from the upper region of the burner may accumulate instead of, as possible in earlier designs, following the air flues down to the recuperator, and a lower one consisting of a system of vertical trap channels communicating with a horizontal flue or pocket and acting as a trap for any flow of glass sideways from the central glass pocket.

In view of its special design, it acts as a safety pocket for the upper one, and adds considerable strength to the whole construction.

It will thus be seen that the recuperator is isolated completely in the following manner : (1) The bottom rests on the foundation. (2) The front and the one side extend to the outside. (3) The top is protected by a system of cooling channels (16). (4) The back is protected by a special glass pocket (12), and the remaining side partly by the producers and partly by special pockets and trap flues (14).

The result is that the recuperator is absolutely safe against any flow of glass.

Method of Working the Furnace.

The furnace can be worked on two different main lines, that of continuous melting and working out, and that of day working— melting by night and working out during the day. In the 10-pot furnace illustrated, with pots of 38 inches diameter, lead glass for bulbs and tubing is melted every night and worked out during the day. This furnace is the largest which can be worked in such a manner; for larger furnaces, the continuous process is necessary.

During the melting period, which takes approximately fourteen to fifteen hours, from the time of ceasing work to starting work, the producers are fired alternately every half hour or hour, depending on the kind of coal used. In this way a steady gas supply is ensured and the temperature increases more uniformly than if the producers

were fired simultaneously. It is important to fire heavily in the beginning of the melting period to ensure a fairly rapid increase of the temperature during this period; also when the maximum temperature has been reached, to allow for the slowing down of the furnace in the right time, as otherwise it may run too hot and damage the pots. The cooling down to working temperature can be done in three to four hours. The producers are clinkered usually twice every twenty-four hours, and care is taken that they are well filled when the working out starts, in which case they need only have an occasional firing during the meal hours, a method which is of importance where open pots are used. (See Temperature chart, Fig. 4.)

The furnace is usually worked by natural draught, the positive pressure of the gas in the producer and of the hot air in the recuperator being more than sufficient to maintain a correct balance in the pot chamber. To speed up the melting and to control unfavourable wind conditions of the chimney, the producer is sometimes blown by steam or by air. The latter works quite satisfactorily, as the step grate is water-cooled and evaporates a fair portion of water, thus saving the installation of a boiler.

Much has been said for and against the built-in producer as compared with the modern mechanical producer. The furnace described is adaptable for both types, but there is no doubt that in fuel consumption and initial outlay the built-in producer type is cheaper and separate producers would only be justified where a big battery of furnaces is required or where other local conditions make it desirable to use such. It is a matter which the author specially recommends the intending buyer to approach with an absolutely open mind and to make the decision solely from an economical and practical point of view without either prejudice or favour for one system or another.

The furnaces can actually be designed so that, if later, a separate producer plant is installed it can be connected without trouble. All that is necessary is to build in an extra arch in the producers and mount gas pipes to the fire-door frames. The step grate below will be kept intact and act as a reserve for the main producer plant, thus saving considerable cost by doing away with a reserve producer. If, on the other hand, anything goes wrong with the producer plant the built-in producer can be put in operation in a few hours.

Where the furnaces are worked on the continuous system, the operation is, of course, very much simplified, as it only consists in firing the producer regularly, and in otherwise keeping the furnace at a constant temperature.
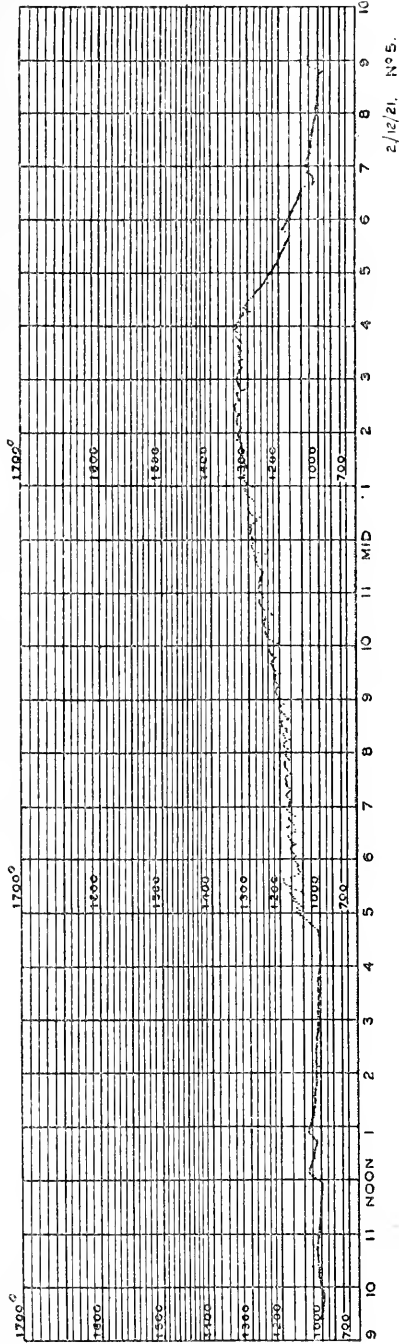
Fig. 4.

Fig. 5 shows a temperature chart of a new 8-pot furnace with tangential burner working on this system at Messrs. Webb's Crystal Glass Co., Ltd., Edinburgh. The producers are also fired alternately and the curve registered is a typical example of the steady temperature maintained in the pot chamber, a matter of some importance when crystal glass is made. It may be remarked that the actual temperature as measured by a Wanner instrument has been found to be, unless otherwise stated, 100—125° (say 115°) higher than is registered on the charts.

Fig. 6, for which I am indebted to Messrs. Philips' Glass Works, Eindhoven, Holland, shows the difference between the working of a regenerative and a continuous recuperative furnace, the one melting by day and the other by night. It will be seen how steady the temperature of the recuperative furnace is as compared with the regenerative. Both are worked out from 8 a.m. to 5 p.m. with the first filling about 6 p.m., the second at 9 p.m., and the maximum temperature reached about 5 a.m., leaving three hours for cooling. Both are working on lead metal for bulbs. The temperatures were registered on a double Cambridge recorder, in this case showing true temperatures. It will be seen that the average temperature of the recuperative furnace is lower than that of the regenerative type, although the melting time is exactly the same, which is a point where the recuperative furnace scores, as it is of influence on the life of the furnace as well as the pot life.

Special consideration has been given to the easy repair of the furnace. The parts which generally wear most in the ordinary gas-fired furnaces are the pillars and siege, especially that part round the burner, and the glass pockets, and only to a smaller extent the waste gas channels, producer walls, and recuperators. It has already been pointed out how the difficulties with the burner and glass pockets and the isolation of the recuperators have been successfully overcome, and when due care is taken at each pot setting to fill up the joints and cracks in the siege with high-class grog, to counteract the corrosion from the glass, the life, which, in older furnaces using covered pots averaged two to three years when melting every night, may readily be expected to be considerably increased in this improved type. It was exactly the wear and tear of these parts which most often brought other types of furnace to a stop.

The recuperator, when built well, should last from six to ten years, which compares favourably with the life of checker work in the regenerative furnace, usually renewed every year on account of being choked with dust, if not for other reasons. Also, in the recent designs, the recuperators can be rebuilt without having to
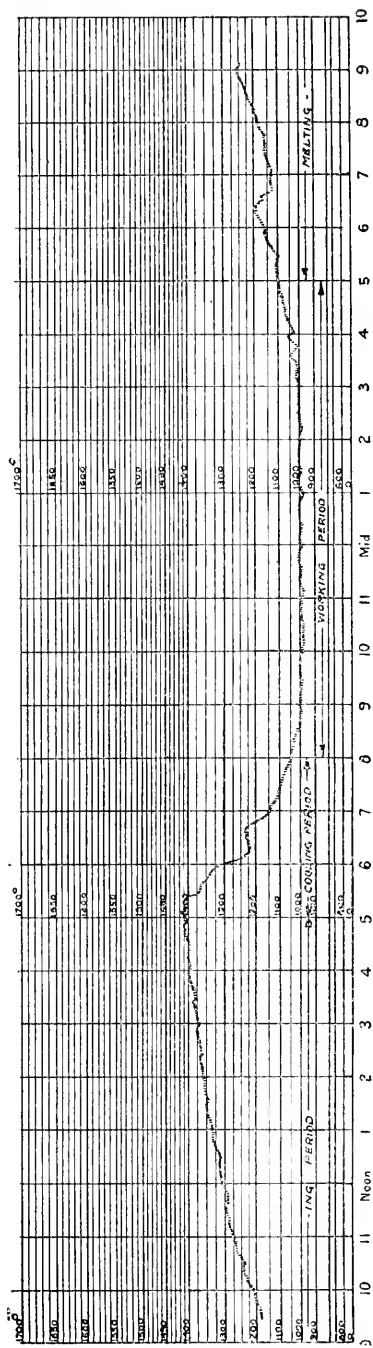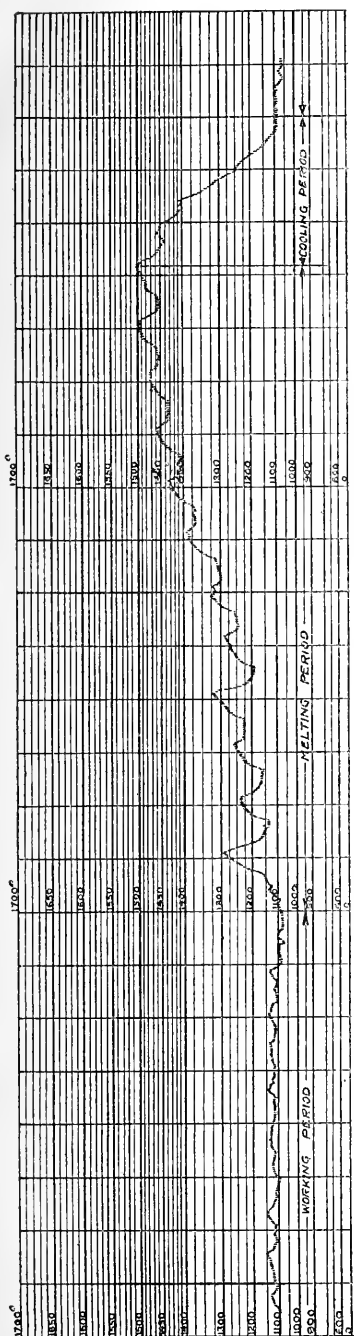
Fig. 6.

pull down any other part of the furnace, and without involving any great cost.

I would like, in conclusion, to add a few general remarks on the relative merits of the recuperative furnace as compared with the regenerative, both of which I have been acquainted with at different times during my practice as an engineer.

My own experience is that although there may be cases where regenerative types are preferable, for most purposes a well-designed recuperative furnace will not only meet the case but be superior both in fuel, repairs, and general running cost, as well as in initial outlay.

The British glass industry, although said to be very conservative, has nevertheless received this new furnace as one of its own, and may I here be allowed to refer to the figures given by Professor Turner in his Presidential Address to the Society on April 26th, 1922, according to which, during the war and the years immediately after, there had been built in this country alone twenty-seven recuperative pot furnaces with 185 pots ?   It has been the author's privilege to design roughly one-half of these, and from his knowledge of their working, as well as from what he has heard about competitive systems, he ventures to state that the recuperative furnace has come to stay in this country, and that other countries will in due course, when things become more normal, see the necessity of adopting the methods which the leading British works have seen fit to do.

Unfortunately, we are passing through a time of difficult, if not to say absurd, conditions of trade, but these must pass over, and then the country, which has seen its way clear to put its industries in order, amongst other means by installing the most modern plant, should reap the benefit of its foresight and enterprise.   This I earnestly trust will be the case with the British glass industry.

In concluding this paper, I would like to thank the different firms, whose names I have already quoted, especially Messrs. The Osram G.E.C. Glass Works, who have kindly supplied me with data and technical information relating to the furnaces installed at Lemington and Wembley, and have also given their kind permission for members to inspect the large 12-pot furnace of this type working at their Wembley works.

52, Grove Avenue,
      Moseley, Birmingham.
      Dec. 12th, 1922.

· DISCUSSION.

THE PRESIDENT said there was no doubt about the author's enthusiasm for his subject, and, although that was not a place where they wished to encourage persons to advertise what they had to sell, nevertheless, as a scientific Society, they were not averse to listening to a man of enthusiasm; and those who differed from Mr. Teisen were properly entitled to criticise the design of the furnace or the design of various parts of it. In regard to the general subject of recuperative furnaces, there was a good deal to justify Mr. Teisen's view that the recuperative furnace had come to stay, because, as a matter of fact, it had come and it was staying. From his own knowledge of the types of pot furnaces being installed in this country, he could say that they were almost invariably of the recuperative type. He had been very much interested, during a visit to Holland some time back, to see in one large works, where there were eight pot furnaces all working under one roof in an immense glass house, that the original furnaces, which were of the Siemens regenerative type, were one by one being replaced by furnaces of the recuperative type, and the manager of the works had told him that this policy was being adopted because the recuperative type was more economical than the regenerative. It had been found there that the consumption of fuel with the recuperative type was, on the average, about 80 per cent. of the weight of the glass worked out. In the particular works referred to, the glass made was bulb metal, with somewhere between 20 and 30 per cent. of lead oxide, and the system adopted was that of melting by night and working out during the day. For this method of working, it seemed to him that there was a good deal to be said, and encouragement should be given to whatever type of furnace would make it possible to melt by night and work out by day. With a large tank furnace, it was obviously impossible, as an economical proposition, to melt at night and work out during the day, but it seemed to him that if one could devise a system which would give the skilled workman opportunities for freedom at night, which his more fortunate brethren in the engineering and other trades possessed, it would be more likely to encourage a better type of workman to enter the glass industry. The night-shift system did not, at least, encourage the attendance at technical classes which was possible in other industries, whereas melting at night and working out during the day did give that privilege to the glass worker in common with those in other branches of industry. He was also interested, when in Czecho-Slovakia recently, to find that the manufacturers there still adhered very largely to the Siemens type

of regenerative furnace. The regenerative furnace, he had been
told there, had a fuel consumption of about 150 tons of fuel to
about 100 tons of glass, whereas it was known that the modern
recuperative furnaces would operate continuously with a con-
sumption of fuel of fewer than 100 tons per 100 tons of glass. In
connection with the construction of the tangential burner in
Mr. Teisen's furnace, he did not know whether a sufficient length
of time had elapsed for anyone to form a judgment as to the life
of that burner, but if any statement upon that could be made, it
would be extremely useful.

MR. F. W. ADAMS asked if Mr. Teisen had noticed any difference
in the wear of the recuperator when using steam as compared with
natural draught on the producer.

DR. M. W. TRAVERS, speaking on the question of melting by
night and working out by day, said this depended on what was
being made in the particular works, and if all the pots were worked
out during the day instead of half during the day and half during
the night. The intermittent system meant that the lehr capacity
had to be doubled.   It was more convenient to work in single shifts ,
particularly as inspection was half the battle, and it was then possible
to check more easily right the way through ; but with certain types
of glass, such as resistance hollow-ware, it was not so easy.   Another
point to be borne in mind when dealing with the question of working
single shifts was that, in the summer months, the night-shift people
thought they were the happy ones, working, as they did, in the
cool of the night. At any rate, that was the case with the night
shift from May to October, and, in any event, no man got night
shift two weeks running.

MR. F. G. CLARK referred to the statement by Mr. Teisen that
the heat in the recuperator did not need to be so high as in the
regenerative furnace to melt the same batch. Could Mr. Teisen
explain why that was so ? He would also like to know what
methods were adopted for cooling down the furnace from the night
shift to get it ready for the day.

MR. J. CONNOLLY asked for data as to the relative pot life as
between the regenerative furnace and the recuperator furnace,
and also as to the pot life when melting at night only and when
working continuously.

MR. E. A. COAD-PRYOR said it always seemed to him to be an
awful come-down to have cooling channels over the recuperators.
He could not help thinking that in the average pot furnace, such
as had been described, it would have been worth while to put in
blocks of fused alumina in order to conserve the heat, and not have
to put in more heat than was required and cool down afterwards.

MR. V. H. STOTT said that Mr. Coad-Pryor had not said all he could on that subject, because, as a matter of fact, he (Mr. Coad-Pryor) had very carefully lagged his own furnace to conserve heat and had not cooled any section.

MR. TEISEN, in reply to Mr. Adams, said he found no appreciable difference in the working of the furnace whether the producer were air blown, steam blown, or working under natural draught.

Replying to the discussion about the lehr capacity required to work by day and melt by night, this difficulty had been met by some continental manufacturers by installing two small furnaces, and working one out by day and the other during the night.

In reply to Mr. Clark's questions, the regenerative furnace temperature was always going up and down, whereas the temperature of the recuperative furnace kept constant or moved up or down progressively. Even if the mean temperature of the regenerative furnace was taken, it was found that it must be run higher than that of the recuperative to melt at the same rate.

With regard to the cooling of the furnace ready for working, when once the glass was fine it was only necessary to begin closing the dampers and slides. In the case of lead glasses, it was sometimes necessary to blow cold air on to the glass, especially in the case of large furnaces.

He was sorry he had no figures at hand to answer Mr. Connolly's questions concerning the life of pots, but he would try to get them.

Answering Mr. Coad-Pryor, the recuperators did not get too hot and therefore did not require cooling. The cooling channels shown were there as a safety device in order to chill any glass that might be flowing towards the recuperators. Any cooling of the recuperators that occurred was incidental, and he agreed that it was to that extent uneconomical, but the safety of the recuperators from molten glass more than compensated for any small loss of heat.

DR. M. W. TRAVERS (communicated).—I have certain observations to make based upon practical experience in the working and construction of recuperative furnaces. I do not consider the placing of the recuperator directly below the siege to be sound engineering practice. A considerable proportion of the load must be taken on the flat arches spanning the recuperator, and however well these are braced externally, the fact that the furnace is a hollow structure, makes it impossible to support the lateral thrusts effectively. The slightest subsidence gives rise to cracking through vital parts of the furnace. The recuperators should be so placed that they carry no part of the load of the siege, pots, pillars, and crown. The furnace can then be so designed that it is unnecessary

to take special precautions, often ineffective, against glass entering the recuperators.

Mr. Teisen appears to have been unfortunate in his experience with furnaces before introducing his patented air ports. As to whether his conclusion as to the behaviour of the air and gas stream is correct must remain a matter of opinion. The admission of air into furnaces in streams tangential to the gas current has, however, been employed to secure the mixing of the air and gas. One would imagine that the gas ascending below the air current would mix with it rapidly. From the diagram it would appear that if the air currents are to be effectively tangential, the material of the outer wall of the air port must form a very acute angle in horizontal section. However, I am in a position to demonstrate the fact that, even when the hot secondary air currents meet the gas stream, below the eye, and at right angles to one another, so long as the design and the materials used are suited to the work, the furnace will not suffer serious deterioration after many months of intensive working.

MR. TEISEN.—In reply to Dr. Travers's communication : several of his remarks have little positive bearing on the subject and scarcely call for reply, but I will try to deal with the more important ones.

So far as the placing of the recuperators below the seat is concerned, this does not create any difficulties. Every civil engineer knows that arches themselves are immensely strong, and to relieve them of the stress is not such a complicated matter as Dr. Travers apparently imagines. It appears that in his criticism on this point he moves on rather uncertain ground. It is interesting to note that it is exactly such works which are amongst the foremost in engineering skill that have adopted this type of furnace, and this again seems to indicate that they are in agreement with the designer in this respect. The same arrangement is used successfully in steel heating furnaces, where the weight in question is far greater and the problems therefore much bigger than in the case of a glass furnace.

In smaller furnaces the recuperators project beyond the top. In larger furnaces, however, the top might be larger than the base ; hence the design employed. It is evident that the more compact the furnace is made, the stronger it is, provided it is correctly designed.

So far as the burner is concerned, Dr. Travers no doubt has observed that there is a tendency in furnaces with radial air inlets to produce a very high temperature in the burner itself, which in conjunction with the chemical action of the glass destroys this part of the furnace before any other. Dr. Travers has tried to

solve this problem in one way, while I have tried to do so in another way. I am fortunate enough to have duly authenticated results from two parallel cases, one from an eight-pot furnace using the tangential burner described in my paper, another from a " Dennis " furnace. Both furnaces are of the same size and melting lead glass for table ware. The first furnace, however, runs at a somewhat higher temperature, making about $1\frac{1}{2}$ melts, while the other furnace makes only one melt, on account of the nature of the work. These furnaces were supplied with blocks of the same material, refractory to cone 34—35, and put into work in March and April 1922, respectively. After nine months' running the edge of the eye in the furnace with my tangential burner was still sharp, while in the " Dennis " furnace it was eaten away 6—8 inches after about eight months' running.

This amount of 6 inches to 8 inches may be no serious deterioration; but, as stated in my paper, I have been out to improve the life of the furnace, and I hope by this design considerably to increase it beyond the two to three years which otherwise is the limit in this class of furnaces with radial air inlets.

Professor Turner has asked whether sufficient length of time has elapsed for any one to form judgment as to the life of this burner. The above remarks, I think, show clearly that there is a difference which points to the advantage given by this design, and I am also able to state that another furnace which has run for fourteen months at a much higher temperature than either of the above mentioned, had still, after that time, the edge quite intact.

I hope, therefore, with this burner design, to have brought something new which will be of benefit to the glass trade, and I am prepared to make it available, subject to proper arrangements, for general use, irrespective of the type of furnace.

It is clear, however, that the principle itself leaves space for variation in detail and the work I have begun will necessarily have to be followed up on methodical lines, which I feel confident will enable me to show still better results at a later date.

II.—*An Examination of some Current Views on the Detection of Strain in Glass.*

By S. ENGLISH, M.Sc.

(*Read at the Sheffield Meeting, January* 17*th*, 1923.)

IN reading carefully through the recent literature dealing with the allied questions of the detection of strain in glassware, and of the annealing of strained glass, a number of statements have been met with which need either qualification or correction. In most of these cases no figures or evidence are given to support the statements, and one is compelled to conclude that in some cases generalisations have been drawn from insufficient data. In order to set on a more sure basis the methods for the detection of strain and its removal from glass, some of these statements need examination.

I.—*The Relation of the Direction of Stress to the Plane of Polarisation of the Light.*

In most papers dealing with the detection of strain in glass, it is stated that the presence of strain (or stress) is shown up by examining the glass in the path of a beam of polarised light.* No reservations are added to this statement, and one assumes, therefore, that the presence of strain is always and under all conditions revealed by examination in a polarimeter. This is by no means the case. It is quite possible to hold a badly strained slab of glass in a beam of polarised light in such a way that on looking through the eyepiece prism no strain is indicated, the field of view remaining dark or practically so. On the other hand, there is one position of the slab in which the intensity of the light reappearing in the eyepiece is at a maximum. This position is the most sensitive one for the detection of strain and the one which should always be used when examining glassware.

Before attempting to fix these positions it is necessary to have some idea of the nature of a beam of polarised light.

A beam of ordinary light is generally looked on as consisting of a very large number of waves or vibrations propagated in straight lines, the direction of vibration being at right angles to the direction of propagation. A very rough idea of a system of this type may be obtained by considering a number of parallel violin strings which have been made to vibrate by plucking or bowing.

* F. Twyman, this Journal, TRANS., 1917, **1**, 61; S. English and W. E. S. Turner, this Journal, TRANS., 1918, **2**, 90; L. H. Adams and F. D. Williamson, *Jour. Opt. Soc. Amer.*, 1920, **4**, 213.

If the violin strings are laid in a horizontal plane, their vibrations which are at right angles to their length may be in any plane that is at right angles to the length of the strings; and if they are vibrating at random there will be some strings moving in each of these planes.

Now if a comb with close teeth be taken and placed across the strings so that on lowering its teeth pass through them, then those strings which were vibrating across the direction of the teeth are brought to rest, and only those vibrating along the length of the teeth are allowed to continue vibrating. In this way, the random vibration of the strings is destroyed and only vibrations in one plane are allowed to remain.

This may serve as a very rough picture of what happens in the production of a beam of polarised light. In a beam of ordinary light as it proceeds from its source, there are innumerable waves vibrating at random in planes which are at right angles to the direction in which the light is travelling. On passing such a beam of light through a Nicol's prism, only the light vibrating in a certain direction is allowed to pass through the prism. Thus, we may picture the emergent beam of light as consisting of waves which are all vibrating in one direction. Such a beam of light is said to be plane polarised, and the direction in which the waves vibrate is called the plane of polarisation.

In a slab of glass which has undergone ordinary cooling, the strain which is left in the glass bears some relation to the shape and size of the slab. Thus in the case of a slab $4'' \times 4'' \times 1''$ the strain lies in strata parallel to the larger faces. If in examining such a slab as this for strain it is held in such a way that the light strikes normally on one of the smaller faces and the long edge of this face is parallel to the plane of polarisation of the light, then no light reappears in the analysing Nicol. If the slab be rotated so that the plane of polarisation is no longer parallel to the strain strata in the glass, light immediately reappears in the analysing prism. If the rotation be continued, the intensity of the light increases, until the angle between the plane of polarisation of the light and the plane of the strain in the glass is 45°. At this angle the amount of light reappearing in the eyepiece is a maximum, as, on further rotation of the slab, the intensity of the reappearing light gradually diminishes until the strain strata are at right angles to the plane of polarisation of the light, in which position the field of view again becomes dark.

It is, therefore, evident that the strain in glass is not detected by polarised light if the glass be held so that the plane of strain is either parallel to, or at right angles to, the plane of polarisation

of the light, and of all other positions the best results are obtained
when the direction of the stress is at about 45° to the plane of
polarisation of the light.

That this fact is not so widely known as is tacitly assumed by
the authors already referred to is proved by the appearance on
the market of a strain viewer described by E. E. Milner.* This
strain viewer, which produces its polarised light by reflection and
uses a Nicol prism as eyepiece, is provided with a stand on which
glassware under examination may be rested. The top surface of
the stand is parallel to, or at right angles to, the plane of polarisation
of the light passing from the reflecter to the Nicol prism. Thus,
if a slab of glass such as has been referred to above is placed on
this stand, it will be supported in one of the two positions in which
any strain present cannot be detected.

II.—*The Design and Use of Strain Viewers.*

During the last six years a number of strain viewers using re-
flection as a means of polarising the light to be used in detecting
strain have been placed on the market. Milner's pattern, which is
of this type, is very little different from one designed and used by
Mr. Follett Osler of Birmingham nearly sixty years ago. In fact
it is so similar that it suffers from the same defect that can be
urged against Osler's strain viewer.

The defect in design is that it is possible for extraneous light,
and for non-polarised light from the diffusing screen, to pass direct
to the Nicol prism, and that with articles of certain shapes it is
possible for partly polarised light *reflected* from the article itself to
pass to the Nicol prism. These sources of non-polarised and only
partly polarised light cause strain to be indicated in articles where
it may not be present at all.

Thus if the neck of a bottle is in the path of the light passing
from the diffusing screen to the Nicol prism it will appear bright
as if badly strained, even although it may be well annealed. Similarly,
the shoulders of a round bottle may reflect light to the Nicol prism
and cause bright areas to be shown up irrespective of the condition
of the glass. Further, in the examination of round bottles, only
the central portion of the bottle allows the light to pass in a straight
line from the reflecter to the analysing prism. The light which
passes through the outer portions of the bottle is more or less
refracted according to the angle at which the light strikes the
bottle sides. On refraction, the plane polarisation of the beam of

* E. E. Milner, *Nat. Glass Budget*, 1921, December 3rd, 14; *Glass Industry*,
1922. **3.** 62.

light is partly destroyed, so that a proportion of the light which passes through the outer parts of the body of the bottle is capable of passing through the analysing Nicol, even although the side zones of the body of the bottle may be perfectly annealed. In the case of round bottles, therefore, even when they are held at the most suitable inclination, the appearance of the middle zone only can be relied on to give an indication of the presence of, or freedom from strain.

III.—*The Use of a Selenite Plate.*

Instead of using the dark field obtained by employing a simple Nicol prism as eyepiece, some strain viewers employ a purple field by interposing a plate of selenite, quartz, or mica in front of the analysing prism. Strains in a piece of glass under examination are then shown up by a change in the colour of the field, either to bluish-green or to reddish-yellow. Some users of strain viewers of this type are under the impression that they can determine whether a glass is in compression or in tension by the change in the colour of the field. The factors controlling this change of colour may be determined by taking a rectangular slab of glass with its strain lying in strata parallel to the larger surfaces, and placing it in the path of the light in between crossed Nicols, the analysing prism being fitted with a quartz or a selenite plate. On placing the glass with its long edges parallel to either diagonal of the polarising prism, any strain that is present is not indicated, and the field of view remains a uniform purple colour. On rotating the slab of glass from this parallel position, however, a change in the colour of parts of the field is immediately seen. The central zone, which is known to be in tension, may change to reddish-yellow, but if the slab be rotated from the original position in the opposite direction, the change in the colour of this zone is to bluish-green, thus showing that the relation between the plane of polarisation of the light and the plane of the strain in the glass is a factor which determines which direction the colour change shall take.

IV.—*The Sensitiveness of Strain Viewers using a Selenite Plate.*

In describing a strain viewer using a selenite plate and the change in colour of the field as a means of detecting strain, Mr. G. V. Wilson * says that " by inserting a selenite plate . . . the instrument is made much more delicate, and comparatively slight strains may be recognised owing to the differences in colour being accentuated." If manufacturers were limited to the use of a weak source of

* G. V. Wilson, this Journal, TRANS., 1919, **3**, 256.

illumination for their strain viewers, then such a claim might be allowed, but in other and more favourable circumstances the plain Nicol prism eyepiece is more sensitive than the eyepiece using a selenite plate.   Moreover, when using a selenite plate, the extent of the change in the colour of the field produced by a piece of strained glass is not influenced by the strength of the light used, increased illumination giving only increased brightness, so that the sensitiveness of the instrument is definitely fixed and invariable.   But when a plain Nicol prism is used as an analyser, the amount of light transmitted through the eyepiece when examining a piece of strained glass is a certain fraction of the incident light, which, of course, may be increased or decreased as desired.   If only rough tests are necessary, then ordinary daylight or a weak source of artificial light may be quite sufficient, but if more sensitive tests are necessary then stronger sources of light should be used.   By increasing the intensity of the source of light, this method may be made so sensitive as to show up such minute strains as are unimportant even in the highest class of optical glass.   Using crossed Nicols in this way, Zschimmer * has shown that very slight strains which are produced in such articles as telescope objectives under the action of their own weight only may be detected.   It is evident, therefore, that plain crossed Nicols with a strong source of light provide a very much more sensitive detecter of strain than any strain viewer using a selenite plate.

Summary.

Strain is not detected in glass by polarised light if the direction in which the stress is acting is parallel to, or at right angles to, the plane of polarisation of the light incident on the glass.   For the best results, the glass should be held so that the direction of the stress is at $45°$ to the plane of polarisation of the light.

Strain viewers should be designed so that no light can pass direct from the source to the analysing Nicol and no light from the source can strike the object being tested and be reflected to the eyepiece, otherwise untrustworthy indications are liable to be obtained.

The use of a selenite or quartz plate in a strain viewer does not enable one to determine tension and compression stresses in ordinary glassware, nor does it render a strain viewer more sensitive except when an extremely weak source of light is being used.

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    THE UNIVERSITY, SHEFFIELD.

* E. Zschimmer, *Zeitsch. Instrumentenkunde,* 1913, **33**, 376.

III.—*The Effect of Various Constituents on the Viscosity of Glass near its Annealing Temperature.*

By S. ENGLISH, M.Sc.

AMONG the fundamental physical properties of glass, one of the most important is its viscosity, because the ease with which a glass flows at various temperatures determines to a very large extent its melting and working properties, and these, in turn, whether or not glassware can be manufactured successfully. Besides influencing these properties, the viscosity of the glass in its nearly rigid condition also determines the temperature at which annealing is most suitably carried out and the range of temperature through which it is necessary to regulate carefully the cooling of the glass.

The annealing temperature of a glass may be looked on as that temperature at which the viscosity just permits the molecules of the glass to move slowly among themselves, and thus relieve any strains that may be present. Littleton and Roberts * have suggested that the annealing temperature of any glass may be determined by measuring its viscosity at various temperatures as it is heated up in an electric furnace, and thus fixing the temperature at which it has the same viscosity as a standard glass has at its annealing temperature.

The rate at which the viscosity of a glass varies with temperature in the annealing region is also a very important practical matter, as the rate of increase of viscosity determines the temperature interval between the annealing point and the point below which there is very little risk of strain being developed by increasingly rapid cooling. On the other hand, the rate at which the viscosity decreases as the temperature is raised above the annealing point determines to what extent a glass may be heated above its annealing temperature without serious risk of deformation occurring. The shape and size of the glass article and the duration of the overheating are also important factors in influencing the tendency to deformation at temperatures higher than that which is necessary for the removal of strains.

* Littleton and Roberts, *J. Opt. Soc. Amer.*, 1920, **4**, 224.   See also English and Turner, this Journal, TRANS., 1918, **2**, 90.

The importance of viscosity data in connection with the annealing of glass has been recognised by Twyman,* who says : " One of the first steps in the series of experiments . . . was the determination of the viscosity for different glasses over a wide range of temperature. . . . The result of my experiments was to show that in the case of all glasses tried, the mobility doubled for every 8° rise of temperature." This is a very wide statement, and one could wish that some data were given showing the kinds of glass used, the actual values of the mobilities with their corresponding temperatures, and the temperature ranges investigated, but no details of any kind were given.

All glass workers know that in the working range the rate at which glasses set, or the rate of increase of viscosity, is not the same for all glasses, and the bottle-blower has summarised this knowledge by calling those glasses, which only stiffen slowly, " sweet." Similarly, at the rather lower temperatures which are used when drawing glass into rod or tube form, the same differences are noticed, some glasses continuing to draw out for a comparatively long time, while others set so quickly that drawing can only be done satisfactorily over a very limited range. It is also well known that lead glasses can be worked both at the furnace and at the bench for a much longer time than can lime glasses, and, on the other hand, it is recognised among glass-blowers that a stiff chilled skin forms in working much more quickly on very dark coloured glasses than it does on pale or colourless glasses.

It is, therefore, very probable that at the working and drawing temperatures all glasses do not have the same rate of change of viscosity with temperature, and it is a matter of interest and importance to determine how far this characteristic rate of setting proceeds, and whether or not Twyman's suggestion of a uniform rate of increase of mobility in the annealing range holds for glasses which are known to have very different working properties. Adams and Williamson,† in a note on the annealing of optical glass, have published some figures computed from empirical equations which are of some interest in this connection, since the rate at which a glass is annealed at a particular temperature is inversely proportional to the viscosity at that temperature. From their equations they have calculated the temperatures at which, in various glasses, a definite amount of strain is relieved in certain fixed times. An extract from their figures is given in Table I, and the difference between the two temperatures is added in the third column.

* Twyman, this Journal, TRANS., 1917, **1**, 61.

† Adams and Williamson, *J. Opt. Soc. Amer.*, 1920, **4**, 213.

TABLE I.

Annealing temperatures.

Kind of glass.	For five minutes.	For ten minutes.	Difference.
Borosilicate crown	575	565	10
Ordinary crown	548	538	10
Light barium crown	583	574	9
Heavy barium crown	619	611	8
Barium flint	530	519	11
Light flint	439	429	10
Medium flint	445	437	8
Heavy flint	434	426	8
Extra heavy flint	412	403	9

From these figures, it is seen that the temperature interval in which the rate of annealing is doubled varies from 8° in the case of the heavy barium crown glass to 11° in the case of the barium flint glass, and that the average interval is rather more than 9°; but in assessing the value of these figures it must be remembered that they are calculated from empirical equations.

Amsler,[*] although quoting Adams and Williamson's figures, and without giving any further reference or experimental data, says, " the rigidity of glass is doubled for every 14° F. fall of temperature." From the logarithm-mobility curve given by Littleton and Roberts [†] it is evident that their standard glass requires a rise of temperature of 12° in order to cause a twofold increase in its mobility.

In order to determine if the mobility was doubled for a rise of 8°, actual measurements of the mobilities of a number of glasses have been made throughout ranges of temperature extending from the annealing points upwards for 150—200°. The glasses tested included practically a full series of soda-lime glasses, a series of four soda-magnesia glasses, two soda-alumina glasses, one soda-lead glass and one potash-lead glass. The mobilities were obtained by measuring the rate at which rods were stretched under the action of a weight at certain fixed temperatures.

An electrical tube furnace (Fig. 7) with the silica tube extending some distance beyond the insulated portion, was fixed rigidly in a vertical position, and was fitted at its upper end with a brass cap, through which passed a platinum rhodium thermo-couple. Threaded into the centre of this cap was a short brass tube with a binding screw, adapted to hold in any desired position a Nichrome wire which supported at its lower end the glass test-piece. Glass rods, 6 inches long, with their ends bent round into the form of a ring, were suspended from a hook on the end of the wire, while another wire was hung from the lower ring. This second wire reached

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[*] Amsler, *Nat. Glass Budget*, 1922 (Nov. 18), No. 29, **1**.

[†] Littleton and Roberts, *loc. cit*.

outside the lower end of the furnace, and carried a long, weighted
needle in the form of a lever supported at its fulcrum by a knife
edge resting against the underside of a flat iron rod.   In the case
of the soda-lime glasses, the lever was weighted so as to exert a
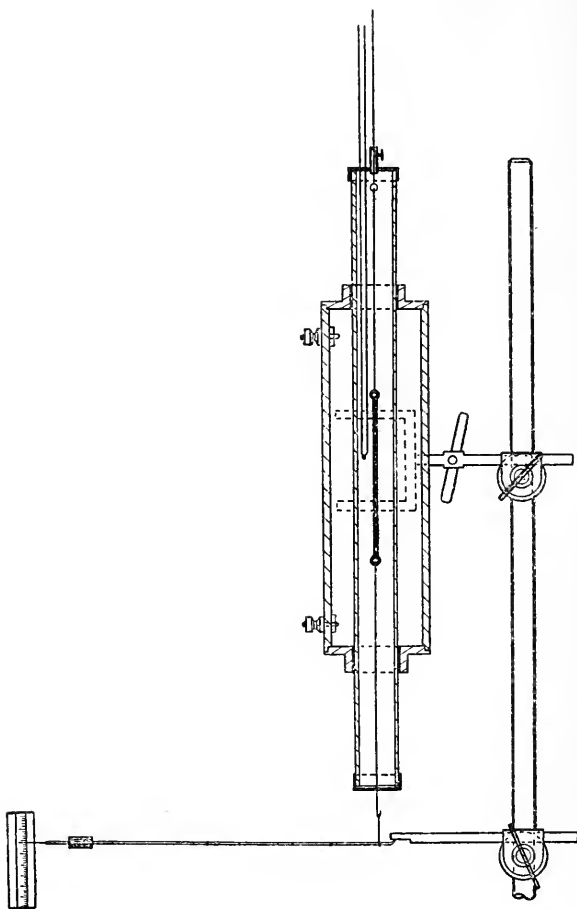
FIG. 7.

pull (including half the weight of the rod) of 10 gm., and was so
proportioned, that the point of the needle soldered on to its free
end, when in front of a millimetre scale with a mirror backing, gave
a reading 10·5 times as large as the actual elongation of the rod.
It was thus possible to obtain very accurate measurements of any
appreciable change in the length of the rods, but at temperatures
near the annealing point the rate of extension was so exceedingly

slow that a very long time (two or three hours) was required to obtain satisfactory readings. To overcome this difficulty in the case of the other glasses used, the effective pull was increased to 200 gm., and the magnification was increased to twenty times for rods of 4·0 mm. diameter through the range of temperature extending to 100° or 125° above the annealing point. For higher temperatures, the thickness of the rods used was 5·65 mm., the effective pull was 20 gm., and the magnification of the extension by the lever was 5·5 times.

In carrying out an experiment, the glass rod was supported by the wire in the lower part of the furnace tube, which was fitted with an inverted cap, with only a ¼ inch hole for the free passage of the lower wire, until the temperature of the furnace had been raised and obtained constant to 1° at the desired level. The supporting wire was then raised and clamped so as to allow the glass rod to hang freely in the middle of the furnace tube. It was held here for three minutes to permit it to reach the temperature of the furnace, and then the weighted lever was hooked on to the lower end of the wire hanging from the rod. Readings of the position of the needle point over the scale and of the temperature were taken at regular intervals, which varied from thirty minutes to five seconds, according to the rate of fall of the needle point. Beginning at or near the annealing point of the glass, measurements were taken at intervals of 25° until the glass became too soft for this method or until devitrification occurred. At each temperature the mean of a number (at least six) of concordant readings was taken and reduced to the rate of fall of the needle point per minute.

Investigation of the variation of temperature in the furnace showed that the middle three inches was constant to within 1°, and that the temperature fell away regularly on each side, so that only the middle portion of the glass was subjected to the highest temperature, and therefore, in each case, whether the glass rods were exactly the same length or not when their ends had been bent round, the same length of each was stretched by the action of the weight. Thus the results given as the rate of extension per minute are strictly comparable among themselves, but they would not be comparable with results obtained in another furnace in which the temperature distribution was different.

To meet this difficulty, it was decided to obtain an absolute measure of the mobility by stretching only a short piece of glass, the whole of it being at a uniform temperature, but otherwise the conditions of the experiment remained exactly the same as were previously used. A potash-lead glass (660) was selected for this

purpose, and three separate determinations of the rate of extension
at 575° were made. Using a 4·0 mm. rod, a pull of 200 gm., and
a magnification of 20, the mean rate of fall of the needle point was
16·0 mm. per minute. A length of exactly 5·0 cm. of this 4·0 mm.
rod was sealed between two short pieces of a glass of high magnesia
content (334) which showed no appreciable elongation at this tem-
perature, the ends of the compound rod were turned just as before,
and the rate of extension at 575° determined. The mean of three
separate determinations gave a scale reading of 6·0 mm. per minute,
or an elongation on the rod of 0·00010 cm. per second per 1 cm.
length.

Defining the mobility as the rate of extension in cm. per second
of 1 cm. length of rod under the action of a force of 1 dyne per
square cm., the mobility (M) of this potash-lead glass at 575° is
given by the following equation :

$$M = \frac{0·0001}{200 \times 981 \times 8} = \frac{1}{157 \times 10^8}$$
$$= 6·4 \times 10^{-11} \text{ (approx.).}$$

This mobility corresponds with a fall of the needle point of 16 mm.
per minute in the ordinary experiments; therefore a fall of 0·01
mm. per minute of the needle point, when using a 4 mm. rod, 200 gm.
pull and a 20 magnification, corresponds with a mobility (M) of
4×10^{-14}. By the use of this factor, it is possible to transform all
the elongation measurements into absolute mobilities, and thus
make them comparable with any other values obtained by this
method.

The Effect of Thickness of the Rod on Rate of Extension.

In order to test the working of the apparatus, and at the same
time to determine how far the thickness of the rods affected the
readings, three rods of the same glass but of different diameters
were used, and the rate of extension of each determined at 600°.
The results are given in Table II, and show that the rate of extension
falls as the thickness of the rods increases, but if the ratio between
the rate of fall of the needle point and the pull on the rod per
square millimetre of its section be determined, a constant value is
obtained.

TABLE II.

Thickness of rod.	Rate of Extension.	Rate of Extension. Pull per sq. mm.
4·3 mm.	0·140 mm/min.	10·2
4·6 ,,	0·128 ,,	10·6
5·2 ,,	0·097 ,,	10·3

The constancy of the ratio in the third column shows that at a fixed temperature the rate of extension is directly proportional to the load per unit area of section.

The Mobility of Different Kinds of Glass.

I. *Soda-lime Glasses.*

The glasses used were the same as those employed previously in the determination of other physical properties. They extend from a sodium silicate having a molecular composition $2Na_2O,6SiO_2$, to a sodium calcium silicate, $Na_2O,CaO,6SiO_2$, the replacement of sodium oxide by calcium oxide being carried out by stages of 0·1 molecule. Thus the molecular composition of No. 4 glass is 1·7 Na_2O, 0·3 CaO, $6SiO_2$, approximately. Details of the composition of these glasses are given in a paper on the annealing temperatures of soda-lime glasses.*

It is well known that glasses which have a high soda content and are low in lime are what glass-makers term "sweet," and for this reason, they are often used for machine-made articles, while, on the other hand, glasses which are high in lime and low in soda set very quickly, and consequently are only suitable for use by hand workers. This series of glasses extending from one (No. 1) with 25·34 per cent. Na_2O and 0·21 per cent. CaO to a fairly high lime glass (No. 11) containing 13·02 per cent. Na_2O and 11·68 per cent. CaO, should show whether this variation in the rate of increase of viscosity as the temperature falls persists down to the annealing point, or whether "sweet" and quick-setting glasses attain a uniform rate of change of viscosity as they approach their annealing temperatures.

The results of the extension measurements are summarised in Table III.

In the case of glass No. 8, the first rod used gave very low readings for the rate of extension between 550° and 650°, but on examination the rod appeared to be quite free from defects or devitrification. At 675, however, the rate of fall at the beginning of the experiment was approximately 3·5 mm. per minute, but it gradually decreased until at the end of 20 minutes it was approximately 2·0 mm. per minute. On taking the rod from the furnace it was found to be devitrified, the crystallisation having apparently spread from one of the end rings which had devitrified during turning. The crystallisation had spread along the surface, and then this hard surface layer had cracked in several places, giving spaces of clear glass which had pulled out and narrowed considerably. The low readings

* English and Turner, this Journal, TRANS., 1919, 3, 125.

TABLE III.

Mobility of Soda-lime Glasses.

Fall of needle point in mm. per min.

Temp.	Glass No. 1	3	4	5	6	7	8	9	10	11
490	0·0022									
500		0·0022								
525	0·040	0·010	0·0075	0·0025	0·0013					
550	0·335	0·095	0·24	0·0167	0·0089	0·0633	0·002	0·0008		
575	1·70	0·52	0·163	0·120	0·033	0·0167	0·016	0·005	0·0022	
600	10·2	3·28	1·10	0·693	0·25	0·140	0·10	0·032	0·01	0·003
625	35·0	13·3	5·05	3·0	1·19	0·75	0·51	0·15	0·057	0·022
650	98·4	72·0	18·6	14·88	4·52	3·5	1·75	0·60	0·287	0·074
675			65·5	47·5	18·6	11·4	5·31	2·0	1·0	0·29
700				188·0	60·1	30·6	23·8	9·0	5·1	1·41
725						108·0	79·5	21·6		7·58
750								81·0		

between 550° and 650° appear to indicate a period of incipient devitrification. It was found impossible to obtain data from glasses Nos. 10 and 11 at temperatures above 700° and 725° respectively, owing to devitrification occurring in each rod used.

These data (Table III) serve to show that as the amount of lime is increased and the amount of soda correspondingly decreased, the glasses become less mobile at any particular temperature, each addition of lime giving a marked decrease in the mobility, a result

Mobilities of soda-lime glasses.
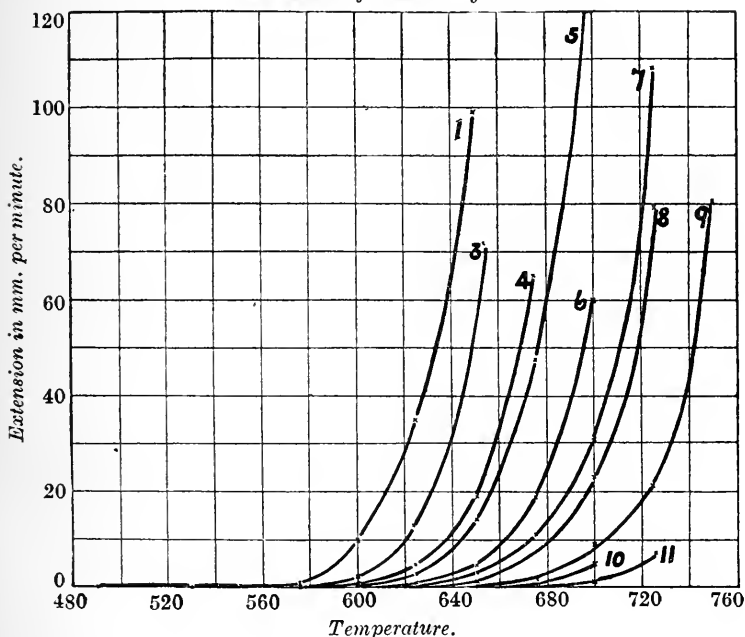
Fig. 8.

to be expected from the progressive rise in the annealing temperature as the substitution of lime for soda is effected.* The figures also indicate that, for each glass, the mobility increases very rapidly as the temperature is raised, but a better idea of how this increase in mobility occurs is obtained by plotting the rate of fall of the needle point against the temperature, as is done in Fig. 8.

The curves obtained are all of a hyperbolic character, and show very clearly how rapidly the mobility of any particular glass is increased by a rise in temperature, and the decreasing mobility

* English and Turner, *loc. cit.*

at constant temperature as the series of glasses is passed through. But the most instructive method of setting out the results is by plotting the logarithm of the rate of fall of the needle point against the temperature, in which case straight lines should be obtained if the curves in Fig. 8 are true hyperbolæ.

Fig. 11 shows the curves obtained in this way, and it is apparent, that each of the lines is nearly straight, and that the whole ten lines are approximately parallel. On closer examination, however, it is seen that the lines show a small curvature, and that in general the curvature decreases as the lime content of the glasses increases, so much so that the curve for No. 11 glass $(1Na_2O,1CaO,6SiO_2)$ is almost exactly a straight line.

To obtain the actual mobilities of this set of glasses, the sodium silicate glass (No. 1) was tested under the same conditions as were used in determining the mobility of the potash-lead glass, No. 660, that is, a rod 4·0 mm. in diameter was subjected to a pull of 200 gm., and the extension magnified twenty times. The readings were carried to higher temperatures by using 5·65 mm. rods, a pull of 20 gm. and a magnification of 5·5, and the results were calculated to the same standard as was used at the lower temperatures, and are included in Table IV.

TABLE IV.

Mobility of Sodium Trisilicate.

Temp.	Rate of fall.	$M \times 10^{14}$.	Temp.	Rate of fall.	$M \times 10^{14}$.
485°	0·046	18	575°	65	26,000
500	0·32	128	600	342	136,800
524	1·87	748	624	1,055	422,000
550	14·4	5,760	650	4,000	1,600,000

In the third column is given the actual mobility calculated by the use of the previously determined factor, and the logarithms of these mobilities are plotted against temperature in Fig. 11 (No. 1 curve). According to this curve, the temperature at which the glass has a mobility of 10^{-9} is 596°, and therefore, by transferring this value of the mobility at 596° to the corresponding curve in Fig. 9, it is possible to get an absolute measure of the mobility of any of these soda-lime glasses at any temperature. On the right hand side of Fig. 9 the logarithms of the actual mobilities $(M \times 10^{14})$ are given.

It is interesting, then, to compare the temperatures at which this glass has definite mobilities as given by the two curves on Fig. 9 and Fig. 11, which were obtained at different times and using different conditions (Table V).

TABLE V.

Mobility.	Log. $M \times 10^{14}$.	Temp. from No. 1 curve, Fig. 3.	Temp. from No. 1 curve, Fig. 5.
10^{-12}	2·0	503°	501°
10^{-11}	3·0	531	528
10^{-10}	4·0	561	559
10^{-9}	5·0	596	596
10^{-8}	6·0	641	642

Log.-mobilities of soda-lime glasses.
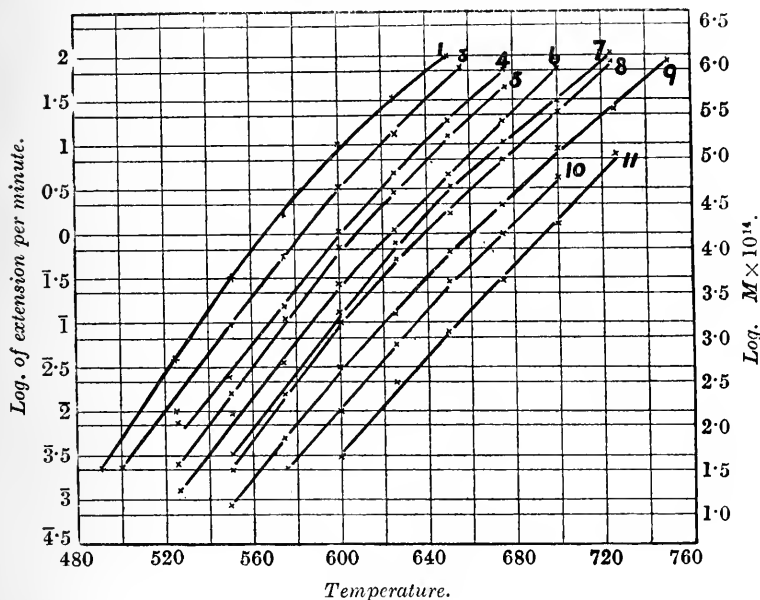
FIG. 9.

The close agreement of the temperatures in the third and fourth columns amply justifies this method of obtaining the actual mobilities of this series of glasses.

From these curves (Fig. 9) it is possible to measure the rate of change of mobility with rising temperature for each of these ten glasses at the annealing point or at any point in the range of temperature covered by the experiments, and thus to test the validity of the assertions (1) that the mobility is doubled for each 8° rise of temperature, (2) that this applies to all glasses, and (3) that it holds over a considerable range of temperature.

The temperature intervals, T, required to double the mobility

in the region of the annealing temperatures for these ten glasses
are given in Table VI.

TABLE VI.

Glass No.	Percentage of CaO.	T.	Glass No.	Percentage of CaO.	T.
1	0·21	8	7	7·45	9
3	2·61	9	8	8·16	9
4	3·81	9	9	9·36	10
5	4·50	9	10	10·38	10
6	6·26	9	11	11·68	11

This temperature interval is nearly constant throughout the
series of glasses, only showing a small but definite tendency to rise
as the proportion of soda is decreased and the proportion of lime
increased.   The result, although not confirming the exactness of
Twyman's statement, does confirm it as an approximate general-
isation, especially for fairly soft glasses.   The small increase in the
temperature interval required for doubling the mobility in passing
from glass No. 1 to glass No. 11 shows that at the annealing tem-
peratures the rate of increase of viscosity for high soda glasses is
quicker than the corresponding rate for high lime glasses, which is
a very surprising result, being exactly the opposite of what is known
to be the case in the working range of these glasses.   This only
applies, however, to the range of temperatures just above the
annealing point, as the bend on the curves for the high soda glasses
corresponds with a reduction in the rate of change of viscosity,
and, in fact, at 150° above their annealing points the soft glasses
No. 1 to No. 9 require a temperature interval of approximately
14° to cause a doubling of their mobilities, whereas the two glasses
highest in lime (Nos. 10 and 11) retain throughout the range in-
vestigated practically constant values for this temperature interval,
namely, 10° to 11° and 11°, respectively.

It is thus evident that the difference in the rate of increase of
viscosity between "sweet" and quick-setting glasses arises at
temperatures some distance above their annealing points, and that
at temperatures from 100° to 150° above their annealing points
the rate of setting is slightly slower for soft high soda glasses than
it is for harder high lime glasses.   If this tendency continues as
the temperature is raised still higher it will account to some extent
for the well-known behaviour of soda-lime glasses in working.

The bend in these curves for the softer glasses is interesting in
another respect, as it shows that the curves given in Fig. 8 are not
true hyperbolæ, and suggests that at higher temperatures still
there will be a point of inflection in the temperature-mobility curves,

and that the interval required to double the mobility in the higher ranges will be very much greater than the 9° required near the annealing points.

II. *Soda-magnesia Glasses.*

Magnesia when added to a glass in place of lime is said to soften the glass and to give it somewhat wider working limits,* although curves given by Field † show that the rates of change of viscosity of lime-silica slags and magnesia-silica slags between 1250° and 1280° are the same for both.   It is interesting, therefore, to investigate exactly the viscosities of a series of soda-magnesia glasses, in order to compare them with the soda-lime glasses, to determine whether or not the corresponding curves are parallel, and at the same time to test the applicability of Twyman's equation to soda-magnesia glasses.   For this purpose five glasses were used, having the following molecular composition.

Glass No.	Mols. Na_2O.	Mols. MgO.	Mols. SiO_2.
1	2·0	0·0	6
26	1·7	0·3	6
329	1·4	0·6	6
332	1·1	0·9	6
334	0·9	1·1	6

Full analyses of these glasses are quoted in the paper on the annealing temperatures of magnesia-soda glasses. ‡

The mobilities for the first 100° or 125° above their annealing points were determined by using 4·0 mm. rods, a load of 200 gm. and a magnification of 20, but for higher temperatures rods of 5·65 mm. diameter were used, the pull was reduced to 20 gm., and the magnification to 5·5 times.   Thus in the second set of readings the pull per square centimetre section of the rod was only 1/20 of the pull used at the lower temperatures and the magnification was 5·5/20 of the previous figure.   In order to convert the readings of the needle point at the higher temperatures to the same standard as those obtained at the lower temperatures, it is necessary to multiply them by 400/5·5.   From the figures thus obtained the absolute mobilities were calculated as in the case of the soda-lime glasses.   The results for No. 1 glass have already been given (Table IV), and the results for the others are contained in the following tables :

* Turner, this Journal, TRANS., 1919, **3**, 37.

FEILD † ~~Field~~, *Trans. Faraday Soc.,* ~~1917,~~ **13**, 3.   1917-18

‡ English and Turner, this Journal, TRANS., 1918, **3**, 278.

TABLE VII.

Glass No. 26.   2·49 per cent. MgO.

Temp.	Extension in mm. per min.	$M \times 10^{14}$.
500°	0·09	36
525	0·6	240
550	4·3	1,720
575	19·0	7,600
600	100	40,000
624	447	178,800
653	1,418	567,200
678	4,127	1,650,800

TABLE VIII.

Glass No. 329.   5·09 per cent. MgO.

Temp.	Extension in mm. per min.	$M \times 10^{14}$.
525°	0·10	40
552	0·85	340
575	3·1	1,240
595	10·6	4,240
630	57	22,800
651	240	96,000
672	764	305,600
700	2,309	923,600
725	4,364	1,745,600

TABLE IX.

Glass No. 332.   7·46 per cent. MgO.

Temp.	Extension.	$M \times 10^{14}$.
572°	0·057	23
602	0·58	232
625	2·3	920
652	10·3	4,120
672	32·0	12,800
700	145	58,000
726	458	183,200
750	1,527	610,800
770	4,436	1,774,400

TABLE X.

Glass No. 334.   9·30 per cent. MgO.

Temp.	Extension.	$M \times 10^{14}$.
600°	0·056	22
625	0·245	98
650	1·00	400
678	4·90	1,960
705	28·0	11,200
725	72	28,800
750	320	128,000
775	1,673	669,200
800	5,454	2,181,600

These results show that at the same temperature the glass with the smaller magnesia content is the more mobile, and that with each glass a rise of temperature causes a very marked increase in the mobility. The curves (Fig. 10) plotted from these extension results are of the same general form as those obtained for the soda-lime glasses, and the curves obtained by plotting the logarithm of the mobility (Fig. 11) are again approximately straight lines, although as in the case of the soda-lime glasses those which are high in soda and correspondingly low in magnesia show a distinct curvature, but as the amount of magnesia is increased the curvature decreases until the curve for the glass (334) with 9·30 per cent. of magnesia is almost exactly a straight line.

The temperature intervals required to double the mobility near the annealing points again show a gradual diminution as the soda is displaced, whilst at the highest temperatures attained the reverse is true, just as was the case with the soda-lime glasses. These temperature intervals are given below in Table XI.

TABLE XI.

Temperature Intervals to Double the Mobility.

| | Glass No. | | | | |
	1.	26.	329.	332.	334.
Percentage of MgO	0·0	2·49	5·09	7·46	9·30
Near annealing point	8°	9°	10°	11°	12°
175° to 200° above annealing point	14°	14°	14°	13°	12°

Mobilities of soda-magnesia glasses.
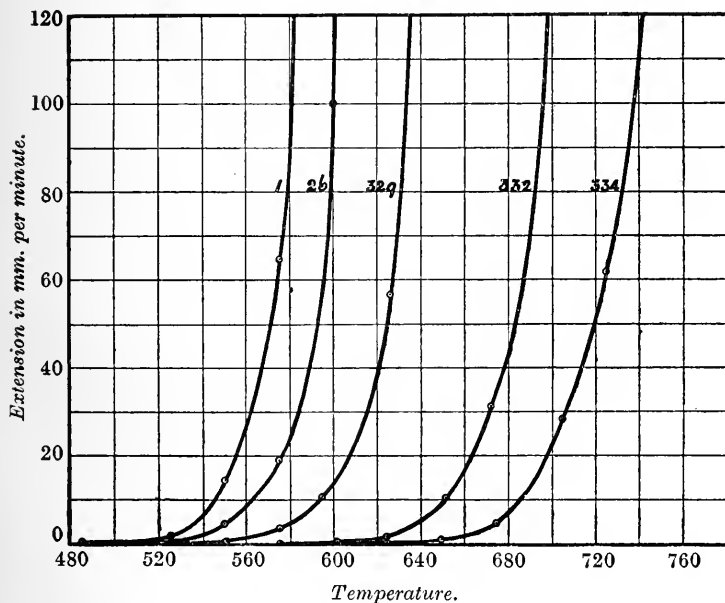
Fig. 10.

These figures show remarkably close agreement with the figures for similar soda-lime glasses, and throughout this range of temperature the curves for the mobility of similar soda-lime and soda-magnesia glasses run practically parallel with each other.

III.—*Soda-alumina Glasses.*

It is generally recognised that the addition of alumina to glass in small quantities has a very beneficial effect on its working

properties in so far as it makes the glass workable over a longer range of temperature. In other words, it decreases the rate of change of mobility in the working range. This effect is pronounced when drawing rod or tube, as an alumina-containing glass can be drawn without difficulty or excessive sagging over a fairly wide temperature range. For this reason, two soda-alumina glasses

Log.-mobilities of soda-magnesia glasses.
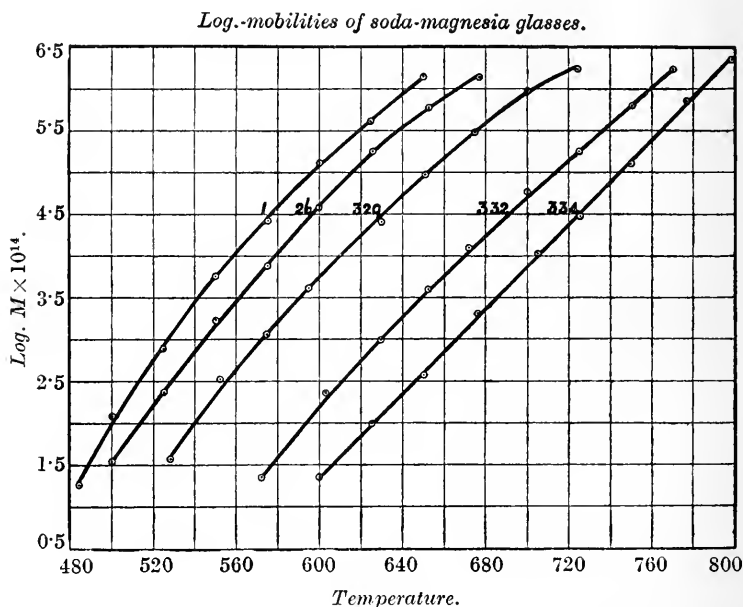
FIG. 11.

of the trisilicate type were included among those tested. The glasses chosen had the following molecular formulæ.

| Glass No. | .... | 443 | $1 \cdot 7$ Na$_2$O | $0 \cdot 3$ Al$_2$O$_3$ | 6 SiO$_2$ |
| Glass No. | .... | 446 | $1 \cdot 3$ Na$_2$O | $0 \cdot 6$ Al$_2$O$_3$ | 6 SiO$_2$ |

Their analytical compositions are given in a paper on the influence of aluminium on the properties of glass.[*]

The mobilities at various temperatures were determined in just the same way as was used for the soda-magnesia glasses and are tabulated below.

* Dimbleby, Hodkin, and Turner, this Journal, TRANS., 1921, **5**, 107.

TABLE XII.

Mobility of Soda-alumina Glasses.

	Glass No. 443. 6·55 per cent. Al_2O_3.		Glass No. 446. 12·69 per cent. Al_2O_3.	
Temp.	Extension.	$M \times 10^{14}$.	Extension.	$M \times 10^{14}$.
500°	0·03	12		
527	0·20	80		
552	1·57	628	0·017	7
575	7·32	2,938	0·13	52
600	33·6	13,440	0·75	300
624	120	48,000	2·2	880
650	560	224,000	10·5	4,200
674	1,600	640,000	31	12,400
695	3,273	1,309,200		
700			120	48,000
725			300	120,000
750			1,125	450,000
775			2,910	1,640,000

Mobility of soda-alumina glasses [1, 443, and 446], soda-lead glass [586], and potash-lead glass [660].
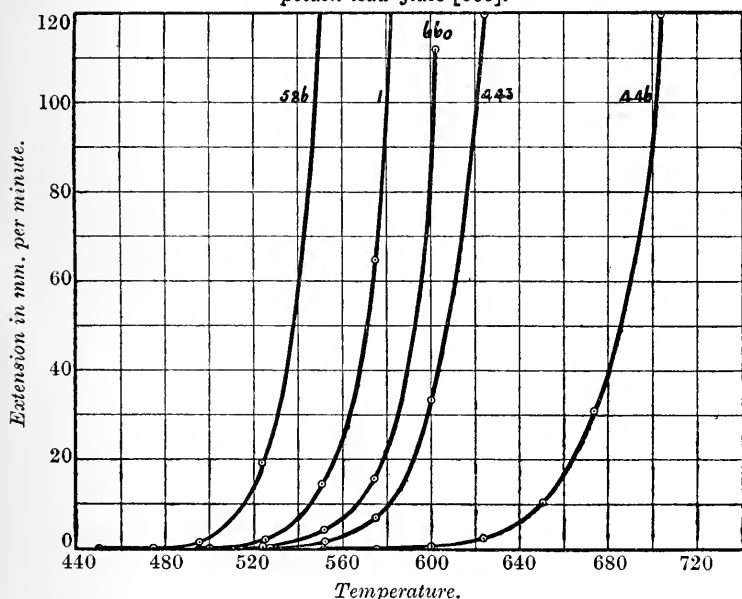
Fig. 12.

These results along with the results for the trisilicate glass free from alumina are plotted in Fig. 12, giving curves 1, 443, and 446, which emphasise the decrease in mobility at any particular temperature due to the addition or increase of alumina, and the consequent decrease in the soda content of the glass. The curves obtained

by plotting the logarithm of the mobility against the temperature
are shown in Fig. 13. The curves for both the alumina glasses are
distinctly curved, and are practically parallel throughout their
course with the curve for the sodium-silicate glass, indicating that
as alumina replaces soda in molecular proportions the viscosity of
the glass is increased, but that the rate of change of viscosity is
practically the same at corresponding points for all three glasses.
There is, however, a tendency for the curve 446 to approach a
straight line at the higher temperatures used, this brings it into
agreement with the high lime and high magnesia glasses.

*Logarithm of mobility of soda-alumina glasses [1, 443, and 446], soda-
lead glass [586], and potash-lead glass [660].*
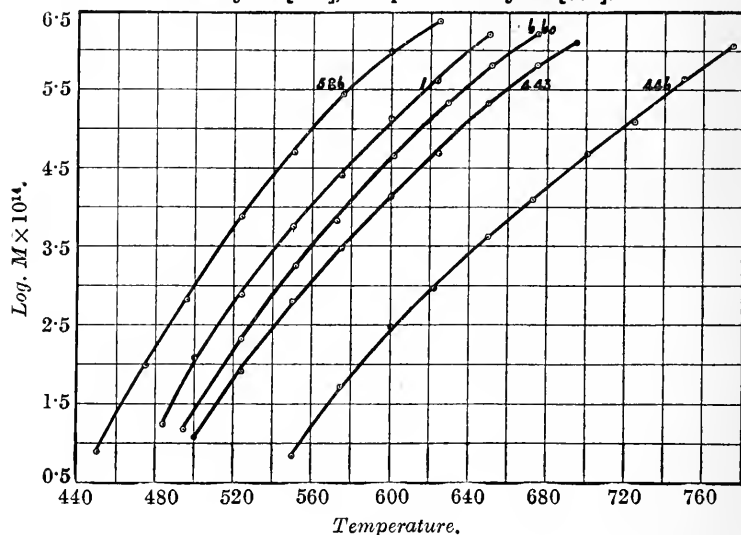
Fig. 13.

In order to double the mobility of these two alumina glasses
near their annealing points, a rise of temperature of 9° is necessary,
whilst at the higher temperatures this interval increases to 14°
for each of the glasses, thus agreeing very closely with the softer
glasses of the soda-lime and the soda-magnesia series. If this
similarity continues as the temperature rises, it will partly account
for the " sweetness " of glasses containing some alumina.

Lead Oxide-containing Glasses.

In order further to test the applicability of Twyman's equation
to various types of glasses, the mobilities of two lead oxide-con-
taining glasses have been determined, one being a potash-lead oxide

glass and the other a soda-lead oxide glass.   The potash-lead oxide glass was a full crystal and was made from a batch of the following proportions : sand 900, red lead 600, potassium carbonate (95 per cent.) 300, potassium nitrate 48, so that the composition of the glass was approximately $SiO_2 = 53\cdot9$, $PbO = 33\cdot4$, $K_2O = 12\cdot7$.

As is well known, a glass of this composition has a long working range which makes it particularly suitable for hand-working processes, and also for the blowing of very thin articles.   Whether this slow rate of change of mobility persists at its annealing point was investigated and the results are tabulated below.

TABLE XIII.

Potash-lead oxide Glass (660).

Temp.	Extension.	$M \times 10^{14}$.	Temp.	Extension.	$M \times 10^{14}$.
495°	0·04	16	602°	112	44,800
523	0·52	208	629	545	218,000
552	4·4	1,760	652	1,600	640,000
574	15·8	6,320	675	4,364	1,745,600

These results are plotted on Figs. 12 and 13 and show that throughout the range investigated the mobility of this glass lies intermediate between mobilities of the sodium silicate and the soda-alumina glass 443.   The log.-mobility curve shows a small curvature, and is parallel to the curve for the sodium silicate throughout its length.   Comparison of this curve with the corresponding curve for the soda-magnesia glass (26) with 2·49 per cent. magnesia, shows that they are practically coincident at each point in the range of temperature investigated.   The temperature interval required to double the mobility near to the annealing point is 9°, whilst at temperatures nearly 200° above this point the corresponding interval has increased to 14°.

The soda-lead oxide glass (586) which was used was specially made for another piece of work, and I am indebted to Professor Turner and Mr. Hodkin for permission to use it in this connection.   It had a composition very similar to that of the potash-lead oxide glass, except for the substitution of the whole of the potash by soda.   In working it was said to be very soft and to have a very long range of temperature in which it was possible to draw rods.   Its mobility was determined, and the results are given below.

TABLE XIV.

Soda-lead oxide Glass (586).

Temp.	Extension.	$M \times 10^{14}$.	Temp.	Extension.	$M \times 10^{14}$.
450°	0·02	8	551°	127	50,800
476	0·24	96	577	669	267,600
496	1·67	668	600	2,400	960,000
523	19·0	7,600	624	6,182	2,472,800

The curve (586) plotted from these results in Fig. 12 shows that the mobility of this glass at any particular temperature is very much higher than that of the potash-lead oxide glass or of the sodium silicate, thus confirming the report concerning its softness. However, the log.-mobility curve (586) in Fig. 13 does not give any in- dication of a very long working range as the temperature interval necessary to double the mobility near the annealing point is 8°, which is only equalled by the sodium silicate glass. At temper- atures 150° to 175° above the annealing point, this interval lengthens out to 14°, corresponding exactly with the potash-lead oxide glass and to the softer glasses of the soda-lime and soda-magnesia series. Although no very slow rate of change of viscosity is indicated in the temperature range investigated, the bend in the log.-mobility curve may develop and cause the interval required to double the mobility to lengthen out much more as the temperature rises still higher. Further, it must be remembered that this glass is work- able at a considerably lower temperature than any of the others investigated, and as a consequence it loses its heat by radiation much more slowly than glasses which are workable at higher tem- peratures. From Fig. 13 it is seen that the mobility of this soda- lead oxide glass at 550° is approximately the same as the mobility of the soda-alumina glass (446) at 705°, but at these temperatures, assuming Stefan's law, a mass of the lead oxide glass would not lose half so much heat by radiation as a similar mass of the alumina glass; consequently its temperature would not fall half so quickly.

In spite of the fact that at these particular points the rate of increase of viscosity with falling temperature is quicker for the lead oxide glass than for the alumina glass, the rate of change of viscosity with time during working is nearly twice as great for the alumina glass as it is for the lead glass. This fact alone seems sufficient to account for the long working *time* of this glass.

Similarly, arguments may be applied with almost equal force to the potash-lead oxide glass, and if such arguments be accepted it appears that the workman's expression that " lead glasses hold their heat much longer than lime glasses " is nearer the truth than any explan- ation of " sweetness " based entirely on the rate of change of viscosity with temperature. The " sweetness " of high soda glasses may be explained to a certain extent in the same way, and the explanation receives general support from the fact that all " sweet " glasses are fairly soft and consequently are workable at comparatively low temperatures. This is, however, not a com- plete explanation, as some glasses which have recently come under the author's notice melt easily and work at fairly low temperatures, but have only a very short working range.

Summary.

Measurements of the mobility of soda-lime glasses, soda-magnesia glasses, soda-alumina glasses, one soda-lead oxide glass and one potash-lead oxide glass show that in spite of their variability in working properties, the rate of change of viscosity near their annealing points is almost constant.   The rise of temperature necessary to reduce the viscosity by one-half in this range being 8° for 2 glasses, 9° for 10 glasses, 10° for 3 glasses, 11° for 2 glasses, 12° for 1 glass.

Thus Twyman's equation is shown to be nearly correct for the range of temperatures near the annealing point, especially for the softer glasses, although it is evident that if a temperature interval of 9° were adopted it would be more in accord with the present results.   It would also be more in agreement with the results calculated by Adams and Williamson.   The equation would then become $M = K2^{\theta/9}$.   This modified equation, however, only applies to the temperatures immediately adjacent to the annealing point, as at higher temperatures the rate of increase of mobility with rise of temperature decreases, and at 175° to 200° above the annealing temperature it generally requires a temperature interval of about 14° to cause the mobility to be doubled.

The results indicate that the mobility is approximately, but generally not accurately, a logarithmic function of the temperature, and that at higher temperatures than those used in this investigation, the mobility-temperature curve for most if not all glasses will have a point of inflection which will to a certain extent determine the " sweetness " or otherwise of the glasses in their working ranges.

The fact that soft glasses are generally " sweet " while glasses which work at higher temperatures are often of the quick-setting variety is no doubt due to some extent to the fact that at their working temperatures the softer glasses lose their heat by radiation much more slowly than do the harder glasses at their working temperatures.   " Sweetness " therefore depends on the two factors (1) the rate of change of viscosity with temperature, and (2) the rate at which heat is lost by the glass at its working temperature. To what extent these two factors are separately effective in determining the " sweetness " of a glass is a matter well worth further investigation.

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    THE UNIVERSITY, SHEFFIELD.

IV.—*The Technical Training of Future Leaders for the Glass Industry.*

By PROF W. E. S. TURNER, D.Sc.

IN writing an introduction to the Sixth Annual Report of the Delegacy which appears in this issue, it occurred to the writer to make a special point of the teaching and training of students who present themselves for systematic courses at the University.   It is to such students, in the main, that the industry should look for many of its future leaders; and although something has been said before about their training, the aims which lie behind it will bear repetition if they awaken a friendly interest and co-operation on the part of manufacturers.

When courses of instruction were first set up for this entirely new departure of applied science teaching, a survey was made of the industry as a whole and of its existing condition and likely development within the following ten years or so.   Having done this, it was recognised that although the various branches of the industry might each have special requirements, the only possible and safe plan was to devise a system whereby the average student at any rate would get a general course of instruction and could adapt himself to any of the branches.   For this reason, therefore, the course of training is not intended to make them expert physicists, first-class engineers, or mathematicians capable of applying the higher methods of mathematics to physical and engineering problems ; but rather, while not neglecting any one of these branches of knowledge, the whole series of subjects essential for a good understanding of modern glassmaking is taught to that standard which the average man should possess before going out into a works in which he may be the sole scientific member, and in which, therefore, there is no chance of specialisation.

Accordingly, a student who enters on a course in the hope of obtaining the degree, namely, the degree of B.Sc.Tech. in Glass Technology, has first of all to pass the matriculation examination and give evidence of a sound general education.   He then enters the University and in his first year of study devotes almost the whole of his time to further work in the fundamental sciences of mathematics, physics, and chemistry, and only in the third term of his first year does he begin to study fairly intensively the properties of glass-making materials and their interaction with one another.

At the end of his first year he must pass the intermediate examination for the degree. If he is successful he then begins to devote himself in his two following years to the applications of science. Thus, he attends a course of lectures on Fuel and its applications in the Department of Fuel Technology, and thereby acquires the knowledge of the scientific principles of the firing of furnaces. In the Engineering Department he takes several courses, comprising the Theory of Machines, Machine Drawing and Construction, and Electro-Technology, including the Transmission of Power. These studies in Engineering are, as already intimated, not intended to make him an expert engineer. Some students naturally have a more definite bias towards mathematics and engineering than others, and such a trait will naturally come out later in the works when the man has to handle machinery. The chief underlying idea, however, is to give the student such a general idea of machinery, the power of reading plans correctly, and the ability to draw and design sections of moulds and simple parts of glass forming machines, that he will not be at the mercy of the mechanic or fitter when he has to go into the works, and he may, indeed, be able to give the mechanic actual assistance and direction.

As the factory can only live and be healthy if it is well managed and there is a proper understanding of the relations between the manual and non-manual workers as well as a knowledge of the uses of capital, the student in his third year attends an outline course on Economics. Finally, the student also attends in the Department of Refractory Materials a course of lectures on that particular branch, and, in the Geology Department, lectures and practical work on Mineralogy as applied to the raw materials of glass-making, refractory materials, etc.

In the Glass Technology Department itself, the student in each of his second and third years attends lectures and practical work for a minimum of fifteen and eighteen hours per week, respectively. In addition to the lecture courses attended he has to acquire a knowledge and some skill in chemical analysis, for the analysis of glass itself is one of the most difficult operations which the average analyst may have to carry out. He is also put through a series of tests on the physical properties of glass, involving such determinations as state of strain, the annealing temperature, the expansion and power to resist heat, tests on all kinds of bottles and containers, the use of the microscope in studying stones, seeds, blisters, and various other defects, and a variety of other tests. He also carries out a number of experimental glass meltings, and, during the past year all students assisted in turn for a few days

in running a large producer gas-fired furnace, the students, in pairs, having charge of the producer and furnace over-night without supervision. They were left entirely with the job.

As far as possible also students have to spend at least six weeks of their long vacation each year in a glass works. This, as well as frequent visits to glass works, helps them to correlate their theory with practice.

To give some clearer idea of what the student has to know on the subject of Glass Technology alone, the following questions are selected as a few from the various examination papers set last summer in the final examination for the Pass Degree.

" It is proposed in a factory making soda–lime glass for containers to substitute fully automatic machinery for hand labour. Discuss the changes in methods which will have to be made in order that successful working under the new system shall result."

" Chemical glassware, miners' lamp-glasses, and cooking ware contain certain constituents in common. What are these constituents, and how do they assist in giving the essential properties required by each type of glass ?

" A glass of the composition $6SiO_2,1\cdot25CaO,1\cdot1Na_2O$ is produced in two factories, in the one case using salt-cake wholly, and in the second, soda ash and salt-cake in the proportion of $2:1$. If the prices per ton of the batch constituents be : sand $16s.$, limestone $24s.$, soda ash £7, and salt-cake £4 $15s.$ $0d.$, what will be the difference in the price per ton of glass melted ? "

" A mistake is supposed to have been made in the batch from which lead crystal glass for tableware has been made. Describe how you would carry out the analysis of the glass and, from the result, ascertain what error, if any, had been made in the batch."

" The two following batches have been used, the first for crystal glass, the second for opal, to be cased over the first :

I.		II.	
Sand	100	Sand	100
Potash	39	Soda ash	23
Limespar	16	Potash	4
White arsenic	0·5	Cryolite	10
		Felspar	10
		Fluorspar	10
		White arsenic	0·5

Using the following cubical thermal expansion factors ($\times 10^7$), ascertain how far the two glasses are suitable to form a combination :—

Cryolite	...	7·4	CaF_2	....	2·5	As_2O_3	....	2·0
Na_2O	......	10·0	CaO	....	5·0	SiO_2	....	0·8
K_2O	....	8·5	Al_2O_3	....	5·0			

Assume for the calculation, that the felspar is

$$K_2O, Al_2O_3, 6SiO_2$$
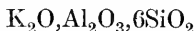
and that no arsenic is lost by volatilisation. What other factors must be taken into account in order to obtain successful welding of two glasses ? "

" Give an account of the way in which you would proceed to test a glass jar so as to ascertain its suitability for use as a jam container."

" A regenerative furnace is fired with producer gas of percentage composition : CH_4 3·2, CO 22·3, H_2 12·4, CO_2 4·1, and N_2 58·0. Calculate the theoretical flame temperature obtainable if the gas emerges into the furnace at a temperature of 900° and the air at 850°. Assume that 25 per cent. excess air is used." [Data for the calculation were supplied.]

" Describe clearly the construction of any form of lehr with which you are acquainted, and explain how it should be operated in order to secure efficient annealing."

" Compare the various methods that are used for mounting on machines the parison and blow moulds for narrow neck bottles. What advantages are derived from each system ? "

" What in your opinion are the present tendencies in the design of automatic feeding devices ? Describe in detail a feeding device illustrating your answer."

" The attached drawing is of a part of a machine for blowing electric lamp bulbs. Using this drawing, describe as fully as you can the mode of operating the machine."

" Discuss fully the phenomenon known as ' after-working ' in relation to the use of glass for scientific and technical purposes."

" What phenomena arising in the manufacture of glass are looked upon as colloidal in character ? Give full details of any evidence in support of this view."

" How may thermal equilibrium diagrams be used in order to arrive at a method of preventing devitrification occurring during the manufacture of a particular glass ? "

" Distinguish between the crystalline phases of silica and discuss briefly their stability relations.

" Which of them do you expect to find in unused silica bricks,
and what is their influence on the behaviour of such bricks ?
What precautions are desirable in using silica refractories ? "

" Discuss the action of heat on fireclay. What is the practical
significance of the changes which take place ? What is the
purpose of the addition of ' grog ' to a fireclay and how
would you determine the desirable proportion to use with a
fireclay or mixture of fireclays ? Discuss the merits of (*a*)
sand, (*b*) burnt fireclay, (*c*) potsherd, as ' grog ' in a pot
clay mixture."

" What factors would influence you in the choice of fuel :
(*a*) for a day-tank furnace, (*b*) for use in a stepgrate pro-
ducer firing a recuperative pot furnace, and (*c*) for a Morgan
gas-machine firing a large regenerative tank furnace ? "

" Describe two methods of determining temperatures in the glass
factory, one suitable for the range from 1000° C. to 1450° C.,
and the other for temperatures from 400° C. to 900° C.
Explain the principles upon which each method depends."

It may be remarked that students for the degree examination
must also possess sufficient knowledge of French and German to
make it possible for them to read scientific literature in these
languages.

In addition to the Pass Degree there is a higher standard still,
and those students who are exceptionally promising may attempt
the Degree with Honours. Students who elect to try for Honours
must now spend three years of study subsequent to passing the
Intermediate examination, instead of two as required only by
Pass students. Such students are required, not only to attend
additional higher courses in Glass Technology, but also to submit
a thesis which involves having carried out some original investi-
gation. There have already been several Honours students.

The next responsibility, which rests as much on the glass industry
as on the Department, is to obtain posts in the works for these
men after they have been trained. The industry ought to be
capable of absorbing a moderate number of such men year by
year for a long time. These men ought to be put into jobs, not
only involving the examination of chemical materials and the
general routine of a chemist's job, but have already been, and
should be more widely, put into charge of batch-mixing operations,
furnace control and lehr control, and give general assistance with
the machines. The aim of the training which they have received
is not simply to make them into analytical chemists ; there would
be no need for a special Department if this were the only end.

While some of them by temperament make more successful analysts than others, many of them find their right sphere in the various sectional operations of the factory itself, and most of them look forward to factory management.

The writer has often stated that a trained man of this type will in the course of a single year save much more than his salary. Additional experience of glass manufacture in this country only confirms him in this belief, and from actual cases within his experience he could show that on the basis of £ s. d. the man had been worth his appointment several times over. It is very desirable in the interest of the industry that many other manufacturers who are still operating without technical assistance should make the venture and engage some such man. They will find little cause for regretting their decision.

The report of the Delegacy which follows tells of various activities, not only in teaching, but also in research of various kinds and of other work done on behalf of the manufacturers themselves.

Sixth Annual Report of the Delegacy for Glass Research for the Year ending 31st July, 1922.

Without doubt the outstanding feature in the year that has passed has been the prolonged negotiations conducted with the Glass Research Association and with the Department of Scientific and Industrial Research in regard to the conditions under which the Delegacy should carry on work for the Glass Research Association. At times these negotiations have caused much anxiety to the Delegacy and probably to all three bodies concerned. Writing at the end of the year, it is possible to say that by continued negotiations difficulties have been gradually surmounted and a common agreement happily reached.

But if the financial and other conditions under which the work has been carried out throughout the year have been full of difficulties, the work itself, fortunately, has been full of encouragement. Both in regard to the work of instruction and the output of research, the high level previously reached has been maintained.

During the year, Miss C. M. M. Muirhead, B.Sc., Research Assistant, resigned on her approaching marriage to a former member of the staff. Owing to the adverse financial position, it has not been possible to appoint a successor.

Professor Turner was also honoured by being elected President of the Society of Glass Technology.

Educational Work.

The number of students taking courses during the day in the Department during 1921–22 was 15, classified as follows :—

Degree Students.

1st year	1
2nd ,,	2
3rd ,,	7

Diploma Students.

2nd year	1
3rd ,,	2

Special Courses 2

Of the seven candidates for the degree of B.Sc.Tech. in Glass Technology, six were successful, two with Honours, whilst eight out of nine were awarded the Diploma in Glass Technology. It is hoped that these graduates who have gone out into the industry will assist the Department in promoting the scientific efficiency of the industry. The Frank Wood Medal was awarded to H. W. Howes.

New ground was broken in connection with the local centre classes by the class started at Glasgow. Other classes were carried on at Alloa, Morley, and Sheffield, the total number of students in attendance being 93. At the end of the first year course, 22 students presented themselves for examination, 13 being successful, one with distinction. At the Intermediate Course examination, 14 candidates were present, 10 passing, one with distinction. Twelve candidates sat for the 3rd year examination, 8 passing, one with distinction.

At the invitation of the Governors of the Sir John Cass Technical Institute, London, a special course of six lectures was given in London, early in 1922, three by Professor Turner and three by Mr. English.

The Lamp-working School.

With the serious depression in the lamp-working branch of the glass industry, the supply of pupils for training fell off in a marked manner during the year. The following record is of the numbers :—

Day Classes.

No. in the School August 1st, 1921 4

Evening Classes.

Total number 8

The Lamp-working School has been of considerable service, not only because of the instruction given, but also because it has made or repaired a good deal of special glass apparatus for various departments of the University. Unfortunately, the pressing need for economy all round forced the Delegacy to close down the work of the School in July and to dispense with the services of the instructor.

The Systematic Research Work.

The following list is a record of the papers published from the Department during the period. Most of the papers have been published in the " Journal of the Society of Glass Technology." Three have appeared in the " Bulletin " of the Glass Research Association.

(1) " Teaching and Research in Glass Technology during 1921," by W. E. S. Turner, D.Sc.

(2) " A Critical Examination of Methods commonly used in Determining the Durability of Glass," by W. E. S. Turner, D.Sc.

(3) " Glass," being a review of the progress in this subject written for the reports on the Progress of Applied Chemistry, by W. E. S. Turner, D.Sc.

(4) " Refractory Materials," being a review of the progress in this subject written for the Reports on the Progress of Applied Chemistry, by W. E. S. Turner, D.Sc.

(5) Article " Glass " in Thorpe's " Dictionary of Applied Chemistry," by W. E. S. Turner, D.Sc.

(6) " The British Glass Industry, its Development and Outlook " (being the President's Address to the Society of Glass Technology), by W. E. S. Turner, D.Sc.

(7) " Lectures on Scientific Glassware " (published by the British Lampblown Scientific Glassware Manufacturers' Association), by W. E. S. Turner, D.Sc., S. English, M.Sc., and others.

(8) " The Action of Various Analytical Reagents on Chemical Glassware," by W. E. S. Turner, D.Sc., and T. E. Wilson, B.Sc.

(9) " The Relative Advantages and Disadvantages of Limestone, Burnt Lime, and Slaked Lime as Constituents of Common Glass Batches containing Soda Ash and Salt-cake," by F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

(10) " The Production of Colourless Glass in Tank Furnaces with Particular Reference to the use of Selenium," by A. Cousen, B.Sc., and W. E. S. Turner, D.Sc.

(11) " The Effect of Magnesia on the Resistance of Glass to
Corroding Agents and a comparison of the Durability of
Lime and Magnesia Glasses," by Violet Dimbleby, B.Sc.,
Constance M. M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.

(12) " The Thermal Expansion of Glasses containing Aluminium,"
by S. English, M.Sc., and W. E. S. Turner, D.Sc.

(13) " The Density of Glasses containing Aluminium," by S.
English, M.Sc., and W. E. S. Turner, D.Sc.

(14) " Some Properties of Lime–Magnesia Glasses and their
Commercial Application," by S. English, M.Sc., and
W. E. S. Turner, D.Sc.

(15) " The Shrinkage, Porosity and other Properties of British
Fireclays after being fired at High Temperatures," by
Edith M. Firth, B.Sc., and W. E. S. Turner, D.Sc.

(16) " The Effect of Chloride in Producing Opalescence in Lead
containing Glass," by Edith M. Firth, B.Sc., F. W. Hodkin,
B.Sc., C. M. Muirhead, B.Sc., M. Parkin, M.Sc., and W. E. S.
Turner, D.Sc.

(17) " The Effect of Chloride on the Melting and Working Pro-
perties of Lead Potash Glass," by Edith M. Firth, B.Sc.,
F. W. Hodkin, B.Sc., Constance M. Muirhead, B.Sc.,
M. Parkin, M.Sc., and W. E. S. Turner, D.Sc.

(18) " Some Properties of Lime–Magnesia Glasses and their
Commercial Application," Part I, by Violet Dimbleby, B.Sc.,
F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

Tests and Investigations for Manufacturers.

That the Department can offer special service in many ways
to individual firms has been increasingly recognised during the
year just past. It is reflected in many ways, including the Balance
Sheet. During the year nearly one hundred visits have been
made, mainly by Professor Turner and Mr. English, to works in
this country, involving about 10,000 miles of travelling, whilst
many interviews have been granted at the Department itself to
manufacturers and others seeking advice on special problems.
The number of cases of inquiry during the year totalled 171, bringing
the total since the Department began work in 1915 to 931.

Of the inquiries for assistance, 103 involved no experimental
work, but the remainder covered a wide range of testing, including
chemical and other tests of special glasses, reports on laboratory
glassware, melting on a considerable scale to test the value of
certain minerals as ingredients for glass-making, tests on bottles
to ascertain their strength or their suitability to hold certain
liquids, tests of jars intended for preserved meats, etc., experiments

THE UNIVERSITY OF SHEFFIELD.

Research Delegacy in Glass Technology.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING JULY 31ST, 1922.

Dr.	£	s.	d.
1921.—July 31st.			
To Balance forward	1,344	7	10
1922.—July 31st.			
To Salaries	3,228	15	10
,, Laboratory Expenses	491	18	10
,, Printing and Stationery	83	17	11
,, Postages	22	6	2
,, Advertising	15	3	9
,, Examination Expenses	5	18	0
,, Incidental Expenses	17	14	11
,, Wages	830	19	6
,, Rates and Insurance	310	0	4
,, Telephones	19	4	2
,, Coal, Light and Water	897	7	0
,, Cleaning	111	14	1
,, Furniture and Fittings	49	2	10
,, Travelling Expenses	95	15	3
,, Bank Interest and Commission	202	13	8
,, Repairs and Alterations	39	2	1
	£7,766	**2**	**2**
1922.—July 31st.			
To Balance forward	1,647	11	8

Cr.	£	s.	d.	£	s.	d.
1922.—July 31st.						
By Grants:—						
Government	50	0	0			
University	500	0	0			
Department of Scientific and Industrial Research	200	0	0			
West Riding County Council	50	0	0			
Society of Glass Technology	50	0	0	1,300	0	0
,, Students' Fees				295	7	2
,, Tests and Researches				4,476	2	6
,, Fees for Lectures				5	2	0
,, Royalties				5	12	5
,, Breakage Receipts				36	8	5
,, Balance forward				1,647	11	8
				£7,766	**2**	**2**

LAMP-WORKING SCHOOL.

Dr.	£	s.	d.
1922.—July 31st.			
To Salaries and Wages	216	2	0
,, Laboratory Expenses	59	11	2
,, Balance forward	149	14	5
	£425	**7**	**7**

Cr.	£	s.	d.
1921.—July 31st.			
By Balance forward	248	11	9
1922.—July 31st.			
By Students' Fees	128	5	6
,, Goods sold	48	10	4
	£425	**7**	**7**
1922.—July 31st.			
By Balance forward	149	14	5

on materials for furnace construction, and a great variety of tests to elucidate works troubles.

Annual Accounts.

It will be seen from the accompanying Income and Expenditure Accounts that on the year's working a loss of about £300 has been sustained, bringing the adverse balance to £1,647 11s. 8d. No grant was received during the financial year from any of the Manufacturers' Associations which have previously regularly subscribed, and for this reason, despite economies and the non-filling of a vacancy on the staff, the accounts could not be squared. It is hoped that with the return of trade, Manufacturers' Associations will find it possible to continue their grants and, if possible, to assist in removing the deficit.

The following is a complete list of the donations received in regard to the Building Fund. Little progress has been made during the year with this Fund, but better trade may presently make it possible for all the promised amounts to be forthcoming.

LIST OF DONATIONS TO THE NEW GLASS WORKS FUND AS AT 31ST JULY, 1922.

	£	s.	d.
Messrs. Bagley & Co., Ltd.	500	0	0
Messrs. Forster's Glass Co., Ltd.	500	0	0
Messrs. Kinghorn Bottle Co., Ltd.	500	0	0
Messrs. Redfearn Bros. Ltd.	500	0	0
Messrs Rylands Glass and Engineering Co., Ltd. (1st and 2nd instalments)	500	0	0
Messrs. John Walker and Sons, Ltd. (Kilmarnock)	500	0	0
Messrs. Wood Bros. Glass Co., Ltd.	400	0	0
Messrs. Kilner Bros., Ltd. (Conisboro') (1st instalment)	250	0	0
Messrs. Garston Bottle Co., Ltd.	150	0	0
Messrs. Law & Shaw, Ltd.	150	0	0
Messrs. North British Bottle Manufacturing Co.	150	0	0
Professor W. E. S. Turner	125	0	0
Messrs. The Co-operative Wholesale Society, Ltd.	105	0	0
G. E. Alexander, Esq.	100	0	0
Messrs. Thomas Barron, Ltd.	100	0	0
Messrs. Beatson, Clark & Co., Ltd.	100	0	0
Messrs. Brunner, Mond & Co., Ltd.	100	0	0
Messrs. City Glass Bottle Co., Ltd.	100	0	0
Messrs. R. Cooper & Co., Ltd. (Edinburgh)	100	0	0
Messrs. Johnson & Jorgensen Flint Glass, Ltd.	100	0	0
Messrs. Jackson Bros. (Knottingley), Ltd.	100	0	0
Messrs. Lewis & Towers, Ltd.	100	0	0
E. D. Libbey, Esq.	100	0	0
Messrs. B. Peacock & Sons, Ltd.	100	0	0
Messrs. E. J. & J. Pearson, Ltd.	100	0	0
Messrs. P. T. Turner & Co., Ltd.	100	0	0
Messrs. P. Waddington & Sons, Ltd.	100	0	0
Frank Wood, Esq.	100	0	0
Messrs. Wood's Glass Bottle Works, Ltd. (Edinburgh)	100	0	0
Messrs. Joseph Boam, Ltd.	75	0	0
Messrs. Gregg & Sons (Knottingley)	50	0	0
Messrs. The Meltham Silica Fire Brick Co.	50	0	0

	£	s.	d.
Messrs. J. Moncrieff, Ltd.	50	0	0
Messrs. Parkinson & Spencer	50	0	0
Messrs. Simon-Carves, Ltd.	50	0	0
Messrs. Stevens & Williams, Ltd. (1st instalment)	50	0	0
Messrs. Dale, Brown & Co., Ltd.	30	0	0
Messrs. A. Gallenkamp & Co., Ltd.	26	5	0
Messrs. J. Arnold & Sons	25	0	0
Messrs. Burtles, Tate, Ltd.	25	0	0
Messrs. Butterworth Bros., Ltd.	25	0	0
Messrs. Davey & Moore	25	0	0
R. L. Frink, Esq. (1st instalment)	25	0	0
Messrs. The General Refractories Co., Ltd.	25	0	0
Messrs. William Nelson, Ltd. (1st instalment)	25	0	0
J. Preston, Esq.	25	0	0
Messrs. Sharp Bros.	25	0	0
Messrs. J. J. Griffin & Sons, Ltd.	20	0	0
The Lead Oxide Convention	20	0	0
Messrs. J. G. Stein & Co., Ltd.	20	0	0
Messrs. Townson & Mercer	20	0	0
" Anonymous "	10	10	0
Messrs. Dennistoun Glass Co.	10	10	0
Messrs. J. Dowell & Sons, Ltd.	10	10	0
Douglas de L'Herman, Esq.	10	10	0
Messrs. Leeds Fireclay Co., Ltd.	10	10	0
Messrs. Scott & Co.	10	10	0
F. Youldon, Esq.	10	10	0
A. H. Adams, Esq.	10	0	0
J. Kaye, Esq.	10	0	0
M. Namba, Esq.	10	0	0
Messrs. Reynolds & Branson	10	0	0
J. H. Steele, Esq.	10	0	0
Works' Collection, Messrs. Wood Bros. Glass Works, Ltd. (Barnsley)	9	0	0
Works' Collection, Messrs. Derby Crown Glass Co.	5	5	6
Messrs. Gay & Wilson	5	5	0
H. Gordon Cameron, Esq.	5	0	0
Messrs. Henry Mead & Co., Ltd.	5	0	0
Messrs. Taylor & Edwards, Ltd.	5	0	0
Professor S. R. Milner	2	2	0
	£6,826	7	6

24th January, 1923.

V.—A Study of the Melting and Working Properties of Boric Oxide Glasses with Special Reference to the Sodium Borosilicates.

By V. Dimbleby, B.Sc., F. W. Hodkin, B.Sc., M. Parkin, M.Sc., and W. E. S. Turner, D.Sc.

(Read at the Newcastle Meeting, February 17th, 1923.)

THE use of boric oxide as a glass-making constituent dates back probably a century from the present time. Faraday's experiments on optical glass-making were carried out on lead boro-

silicates,* and, in a work published in 1832,† borax is mentioned as being used only in preparing the finest descriptions of glass, plate glass being specially mentioned. Gillinder,‡ in 1854, says of borax that " it is invaluable in any coloured metal where a strong flux is wanted; it is the strongest alkaline flux yet known." W. V. Harcourt § also investigated the influence of boric oxide on the optical properties of glass, combining the oxide with a number of metallic bases.

It became of real practical importance, however, after the investigations of Schott and his co-workers at Jena during the last twenty years of the nineteenth century. Two special properties of boric oxide were then established, in addition to its known fluxing effect and its special influence on the refractive index, namely, its power of increasing the resistance of glass to chemical corrosion and the reduction in the coefficient of expansion which it brought about.

Many practical applications followed. Not only did boric oxide become of increased importance in the manufacture of different types of optical glass, but thermometer glasses of low depression constant and small coefficient of expansion, chemical glassware and illuminating glassware, such as chimneys and miner's lamp glasses came on to the market. The chimneys and the miner's lamp glasses contained as much as 17 per cent. of boric oxide, and the total amount of the acidic oxide present was at least 90, ‖ soda being the only basic constituent.

After something of a lull in the exploitation of the borosilicate glasses, the war period has again brought them into prominence. All the British and American types of chemical glassware developed since 1914 contain boric oxide in varying degrees.¶ But the most important development has been the manufacture of Pyrex glass containing approximately 80 per cent. of silica and 12 per cent. of boric oxide,** and its use for chemical glass, articles for cooking purposes, domestic glassware such as feeding bottles and teapots, and, on the large scale, for chemical plant. Illuminating glassware, chemical glassware, and cooking ware are also being produced in Great Britain from a glass rich in boric oxide, and so far

* Bakerian Lecture, *Phil. Trans.*, 1830, **120**.

† *The Origin, Progressive Improvement, and Present State of the Manufacture of Porcelain and Glass*, Longman, Brown, Green & Longmans, London, 1832.

‡ *The Art of Glass Making*, p. 16.

§ *Brit. Assoc. Report* (by G. G. Stokes), 1871, p. 38.

‖ E. Zschimmer, *Die Glasindustrie in Jena*, 1909, p. 142.

¶ This Journal, TRANS., 1917, **1**, 153.

** This Journal, TRANS., 1918, **2**, 219.

as we are aware, there is no new development of chemical-resistant or heat-resistant glass in the old world or the new (other than fused silica) which is not based largely on the use of boric oxide.

Despite the importance which boric oxide has assumed in the glass industry, the volume of published researches concerning glasses containing it is not large. Undoubtedly the research workers attached to the large factories in Europe and America where borosilicate glasses have been made must have acquired data concerning its properties, but for the sake of general progress it seemed to us that some systematic investigations should be carried out and the results made available for the industry in general. Hence the present series of papers.

The Miscibility of Boric Oxide with other Oxides.

Both Guertler * and also Burgess and Holt † have shown that homogeneous liquids are by no means always formed by fusing boric oxide with other oxides. In the case of silica, Guertler includes it amongst the oxides which are either insoluble or but slightly soluble in boric oxide. Bleininger and Teetor, ‡ however, prepared fused mixtures of boric oxide and silica, presumably homogeneous, of composition lying between B_2O_3 and $B_2O_3,3SiO_2$, for experiments on the heat of solution and other properties.

Valuable information on the influence of boric oxide in borosilicates should be obtainable from a study of the two component mixtures without the complicating effect of soda, but for the present we have to postpone the consideration of these simpler mixtures. Mr. A. Cousen, in this laboratory, has made meltings, in varying proportions, of mixtures of silica and boric oxide at 1400°. The mixture with 70 per cent. silica and 30 boric oxide yielded only a boily, opaque mass after seven hours' heating; the 50/50 mixture gave a semi-opaque substance after six hours, and after forty-eight hours two layers, namely, a clear upper layer and a stiff, opaque layer. Two layers were likewise obtained with the proportions 30 silica, 70 boric oxide; and with 20 silica, 80 boric oxide. So far, only the mixture of 5 silica and 95 boric oxide has given a glass at 1400°, although the whole range has not yet been worked over. The effect of higher temperature melting remains yet to be determined.

In the glasses now described, soda has been added to obtain glasses readily. There were suggestions even here, during the

* *Zeitsch. anorg. Chem.*, 1904, **40**, 225, 337.
† *Proc. Chem. Soc.*, 1903, **19**, 221; *Trans. Cer. Soc.*, 1905—1906, **5**, 163.
‡ *Trans. Amer. Cer. Soc.*, 1912, **14**, 210.

melting operations, of segregation, a variation in the depth of colour in different layers of the glass being apparent, the brown colour produced getting deeper as the distance from the surface increased. A number of experiments, both on the molten glass and on specimens at the ordinary temperature, were carried out, to test whether or not segregation into layers did actually occur.

Thus, with the glass No. 611/2, two proof samples (a and b) were taken at intervals from the surface, one from each side of the pot, and the density at $25°$ carefully determined after crushing and annealing the glass. The results found were as follows :

Time in pot.	Density.	Time in pot.	Density.
6 hours.	(a) 2·3217	9 hours.	(a) 2·3209
,,	(b) 2·3217	,,	(b) 2·3209
7 hours.	(a) 2·3218	10 hours.	(a) 2·3208
,,	(b) 2·3218	,,	(b) 2·3208
8 hours.	(a) 2·3208	11 hours.	(a) 2·3210
	(b) 2·3206		(b) 2·3212

The second set of samples (after seven hours) was taken immediately before stirring the glass, the result of which was to cause a fall in the density of one unit in the third decimal place, traceable to one or more of several factors, but in any case very small in amount. Thereafter, the density remained practically constant for four hours.

In two other cases, the refractive index (n_D) of samples was determined. With glass 612, samples were gathered from a 28 lb. pot at different depths, the colour of the glass becoming progressively browner. In the second case, a small experimental pot with glass about 15 cm. deep was slowly cooled to obtain a lump, and segregation, if such was possible, should have occurred by this treatment. The lump was sliced into layers and three selected for test from the top, middle and bottom. The results were :

Glass 612.		Small pot.	
Sample.	n_D.	Sample.	n_D.
a (top)	1·48823	1	1·48924
b ,,	1·48830	2	1·48930
c ,,	1·48823	3	$\begin{cases} 1·48978 \\ 1·48937 \end{cases}$
d ,,	1·48836		
e ,,	1·48743		
f (bottom)	1·48769		

The specimens gathered or cut from the bottom in each case were marred by numerous fine cords which caused differences of three or four units in the fourth place. Remembering this, it appears to have been demonstrated that, in the sodium borosilicates described in this paper, no segregation into layers occurred ; in other words, homogeneous glasses could be prepared.

The Preparation of the Glasses.

Although glasses with a greater percentage of silica might have been obtained by not limiting the temperature, it was decided to maintain, for comparison purposes, the uniform value of 1400° as the temperature of melting. Covered pots of 28 lb. capacity were used and the materials and their proportions were as stated in Table I.

Most of the glasses were not stirred, but certain others were, and these are indicated in the table. We were not able to ascertain that any improvement was brought about as the result of stirring; indeed, in some cases, the effect appeared to be detrimental rather than advantageous.

TABLE I.

	Batch composition. Parts per 1000 of sand.			Calculated approximate percentage composition of the glass.		
Glass No.	Soda ash.	Borax anhyd.	Boric acid.	SiO_2.	Na_2O.	B_2O_3.
600	427·5	nil.	—	80	20	—
601	406	96·4	—	75	20	5
602	380	206	—	70	20	10
603	351	289	—	67	19·65	13·4
604	351	330	—	65	20	15
605	320	481	—	60	20	20
606	229	866	—	50	20	30
607	98	1442	—	40	20	40
608	5	1885	—	35	20	45
609 609/2*	19	780	—	55·8	14	30·2
609/3 609/4‡	19	415	—	70	10	20
609/5 609/6‡	234	—	506	70	10	20
610‡ 610/2	74·2	290	—	75	10	15
611 611/2†	263	—	683	65	10	25
612 612/2†	274	—	886	60	10	30
613† 613/2	311	—	1127	55	10	35
614 614/2†	342	—	1417	50	10	40
615/2	380	—	1772	45	10	45
616†	508	—	2215	40	10	50
617 617/2	155	—	1290	55	5	40
618	171	—	1592	50	5	45
619†	143	—	975	60	5	35
620	132	—	818	65	5	30
621	122	—	632	70	5	25
622	114	—	472	75	5	20

* Stirred once.   † Stirred twice at intervals.

‡ Stirred three times at intervals.

The borax used in making up the batches was the crystallised variety, namely, $Na_2B_4O_7,10H_2O$. As variations in the total water in the borax occurred from sample to sample, allowance for which had to be made, the table has been simplified by stating the amount of borax used as anhydrous borax, $Na_2B_4O_7$.

The Rate of Melting and Refining.

The replacement of silica by boric oxide (the amount of sodium oxide remaining approximately constant) was accompanied by a very distinct reduction in the time needed to obtain the glass batch-free. A marked improvement also was found in the rate of elimination of the seed or bubbles from the glass.

TABLE II.

	Per cent. B_2O_3.	Time to obtain batch-free (minutes).	Time to obtain seed-free (hours).
Glasses with 20 per cent. Na_2O.	0	120	after 22
	5	90	3
	10	60	2
	13·4	50	2—3
	15	45	2—3
	20	45	2
	30	30	1, but fine seed reappeared on working.
	40	20	$\frac{3}{4}$,, ,, ,,
	45	15—20	$\frac{3}{4}$,, ,, ,,
Glasses with 10 per cent. Na_2O.	{ 15	420	Seedy throughout.
	{ 15	420	Less seedy than above.
	{ 20		Some seed after 8 hours.
	{ 20		,, ,,
	{ 20		,, ,,
	{ 20	150—180	,, ,,
	{ 25		10
	{ 25		11
	{ 30		10
	{ 30		9
	{ 35	60	8
	{ 35	60	8
	{ 40	60	11
	{ 40	60	$6\frac{1}{2}$
	{ 45	45	3—4
	{ 50	30—45	2
Glasses with 5 per cent. Na_2O.	20	Not in 17 hrs.	Very seedy.
	25	About 17 hrs.	Much fine seed.
	30	30 hrs.	
	35	45 mins.	Nearly free in 3 hrs.
	{ 40	45 ,,	,, ,,
	{ 40	45 ,,	3
	45	30—45 mins. 3—4	

In order to give a more complete account of this increase in the rate of melting, a table (Table II) has been drawn up setting out

approximately the time needed from the beginning of charging the batch until the glass was batch-free and similarly the time from the commencement of operations until the glass was free from seed. The results very clearly indicate the improvement in both melting and refining with increasing boric oxide content.

It will be noticed that in the glasses containing approximately 20 per cent. of sodium oxide the improvement in the rate of melting and refining was steady and continuous. In the glasses with 10 per cent. of sodium oxide the range of glasses could be distinctly divided into three groups.

When the glass contained approximately 15 per cent. of boric oxide and 75 per cent. of silica the melting was prolonged, seven hours being required for its completion. With 20 per cent. there was a sudden improvement, the melting period dropping from seven to between two and a half and three hours. This melting period held good approximately up to about 30 per cent. of boric oxide, after which there was a further sudden drop, namely, when 35 to 50 per cent. of boric oxide was present.

An observation which seemed to us to be of very considerable practical importance concerned the relative fluxing * value of soda ash and borax. Boric oxide and borax have always been regarded as very valuable fluxes and we have already quoted Gillinder's statement in regard to the fluxing value of the latter. Our observation showed, however, that soda ash is far superior to borax, at any rate in glasses of the type with which we are dealing in this paper, and we may add that we have found similar results in somewhat more complex mixtures.

Thus, it will be noticed that whereas the glass containing silica 75, sodium oxide 20, and boric oxide 5 per cent., melted in ninety minutes, seven hours were required for the batch silica 75, sodium oxide 10, boric oxide 15; whilst when the proportions were silica 75, sodium oxide 5, boric oxide 20, the batch had not melted completely even in seventeen hours. Similar comparisons throughout the series recorded will reveal the same definite phenomenon. Moreover, in some meltings carried out in a small crucible, mixtures containing silica 85, sodium oxide 5, boric oxide 10, and silica 80, sodium oxide 5, boric oxide 15, were not completely melted at 1400° after being heated for some four hours, whereas a mixture of 80 silica, 15 sodium oxide, and 5 boric oxide melted fairly readily.

A comparison was made also with the glass containing silica 70,

* The term "fluxing" is used here in the rather ill-defined factory sense rather than the scientific. A real comparison of the action of the two substances could only be made by a more systematic scientific investigation which our results may suggest to some worker to carry out.

sodium oxide 10, boric oxide 20, between borax and boric acid as
sources of boric oxide. No essential difference was found between
the two glasses in point of melting and working.

The important fact to stand out in this section is that soda ash
is quite distinctly superior to borax in assisting the melting oper-
ation. Whilst this appears to be contrary to general belief, the
results should not be taken as a recommendation to leave out
borax and add more soda ash in those cases where the glass already
contains a fairly large proportion of alkaline oxides. If a little
further fluxing effect is necessary it should be borne in mind that
although soda ash may be more effective in this particular, the
boric oxide which accompanies the alkaline oxide in borax has, in
small amounts, a very beneficial influence in improving the durability
of the glass, whereas increasing the alkaline oxide only has precisely
the opposite effect and is detrimental to the glass.

TABLE III.

Glass No.	Per cent. B_2O_3 added.	Time in pot.	Working temp.	Character of glass.
600	0	22 hrs.	1250—1200°	High initial viscosity; long working range; drew easily.
601	5	22 ,,	1200—1150°	Very soft at 1250°; long working range but rather quick setting at about 1000°.
602	10	20 ,,	1120—1070°	Very fluid at 1200°; easy working at 1100°, followed by rapid increase in viscosity.
603	13·4	20 ,,	1050—1000°	Works best from 1050° downwards.
604	15	5½ ,,	950°	Too soft even at 950—1000°; six gatherings necessary to obtain even a 12 oz. parison. Very short working range and outer skin set rigid on marvering.
605	20	7 ,,		Similar to above (Glass 604).
606	30	2 ,.	950—900°	Very fluid with rapid change of viscosity. Very difficult to work.
607	40	3 .,		At 1000° like oil. Not possible to work due to rapid setting.
608	45	3 ,,		At 900°, even 10 gatherings did not give a parison of 16 oz. Could be ladled like water, but set extremely quickly.

Glasses with 20 per cent. Na_2O.

TABLE III (*contd.*).

Glass No.	Per cent. B_2O_3 added.	Time in pot.	Working temp.	Character of glass.
610 610/2	15	$9\frac{1}{2}$,, 12 ,,	1300°	Fair working range, but too viscous at 1200° for working.
609/3 609/4 609/5 609/6	20	9 ,, 12 ,, 12 ,, 12 ,,	1250—1200°	Quite fluid at 1100°; fairly good working range; tubing drawn readily.
611 611/2	25	12 ,,	1220—1190°	Restricted working range.
612 612/2	30	12 ,,	1180—1130°	Not difficult to work but set quickly.
609 609/2	20·2 *	$3\frac{1}{2}$,, 8 ,,	1050—1000°	Like oil at 1100°; quick setting and working range too restricted for practical operation.
613 613/2	35	12 ,,	1120—1070°	Very soft at 1150° but set quickly.
614 614/2	40	12 ,,	1100—1050°	Very soft at 1200°; rapidly developed a skin on marvering and became difficult to work. Opalescence liable to appear on re-heating.
615/2	45	6 ,,	1100—1050° *	Extremely fluid at 1150°; set rapidly; practically no working range.
616	50	$4\frac{1}{2}$,,	1100—1050° †	Extremely fluid; seven gatherings needed for 7 oz. parison. Working impossible.
622	20	?	?	Not completely melted and higher temperature than 1400° required.
621	25	21 ,,	1380—1350°	Very viscous, but long working range.
620	30	32 ,,	1380—1350°	Viscous, but worked well.
619	35	8 ,,	1300°	Developed crystalline nuclei and became un-workable.
617 617/2	40	7 ,,	1300°	Practically no working range.
618	45	5 ,,	1300°	Set with great rapidity.

Glasses with 10 per cent. Na_2O. (rows 610 through 616)

Glasses with 5 per cent. Na_2O. (rows 622 through 618)

* This glass contained 14 per cent., not 10, of sodium oxide.
† Could not cool lower because of tendency to opalescence.

The Influence of Boric Oxide on the Working of Borosilicates at the Furnace.

W. V. Harcourt found that the phosphates and borates differed from the silicates in possessing a much smaller viscosity. We ourselves found striking reductions in the viscosity of the glasses and a very great increase in the rate of change of viscosity as the proportion of boric oxide was increased; and ultimately the process of gathering and working the higher boric oxide glasses into tubing became an impossibility. This was the case, for example, with glasses of the following approximate compositions :

SiO_2.	B_2O_3.	Na_2O.
40	40	20
35	45	20
50	40	10
45	45	10
50	45	5

In various other cases, working was carried out only with great difficulty. Table III represents an attempt to summarise our experience.

Several noteworthy phenomena were observed in some cases on attempting to work out the glass from the pot. In the first place, a thin, hard film or scum was observed to develop on the surface of some of the glasses containing 10 per cent. of sodium oxide soon after the stopper of the pot was removed, although initially there was no trace of the scum. This scum, which was white and flaky and had to be raked off from time to time, occurred over the range 15—30 per cent. of boric oxide, diminishing as the latter increased. It is conceivable that the film consisted of silica which separated as the result of the volatilisation of boric oxide; it is to be noticed that the silica content was highest in those glasses exhibiting this behaviour, whilst the percentage of sodium oxide (Na_2O) was probably not sufficient to prevent devitrification as the B_2O_3 was lost by volatilisation.

The second phenomenon was the recurrence of seed in the glasses containing the higher proportions of boric oxide, particularly glasses 606, 607, and 608 in the 20 per cent. Na_2O series, containing approximately 30—45 per cent. of boric oxide.

This evolution of gas bubbles appeared to occur when the glass was disturbed by the insertion of a gathering iron, and might be due either to the liquid being supersaturated with gas, or to more active volatilisation of B_2O_3 on disturbing the surface. As the viscosity diminished rapidly with increase of boric oxide content, the tendency to supersaturation would be expected to diminish

rather than to increase, and we are inclined, at the present state of our observations, to consider volatilisation of boric oxide to be the main cause.

Thirdly, separation of solid matter throughout the mass took place with glasses 619 and 620, particularly with the former; both glasses contained 5 per cent. Na_2O. Glass 619, with 35 per cent. of boric oxide, was at first quite free from seed, and contained but a few white specks. In a short time after the pot stopper was taken down and the gathering of the glass commenced, large numbers of these specks developed, producing stony glass which broke into lumps on being drawn. It is possible that the phenomenon may be related to the development of opalescence which is referred to below.

Lamp-working Properties and Hardness.

In experiments on sealing up and drawing out the glass tubing —in those cases where samples of tubing were available—the following observations were made on the lamp-working properties :

	Glass No.	Per cent. B_2O_3.	Lamp-working behaviour.
20 per cent. Na_2O.	0 0	0	Very soft and easy working.
	601—603	4·46—11·34	Soft, good working.
	604—605	14·45—18·84	Worked well, but slightly hard.
	606—608	28·83—43·70	{ Became progressively softer, 608 being very soft.
10 per cent. Na_2O.	610/2	12·45	Worked well.
	609/6	18·71	Worked well, softer than 610/2.
	611—612	21·81—25·82	Rather soft; easily blown.
	613—616	31·26—46·07	Very soft.

None of the glasses was found to undergo devitrification on being worked.

Some interesting observations were made on the hardness of the glasses. It is well known that borosilicate glasses used for modern scientific apparatus are hard and not easy to etch with hydrofluoric acid, so that badging is usually done either with an enamel or by sandblasting. We found that in the series of glasses containing 20 per cent. Na_2O, it was especially difficult to cut with a file those numbered 602—605. This set covers the range in which the maximum annealing temperature occurs. Glass No. 604, with 14·45 per cent. B_2O_3, was specially resistant to the file. We may note, although we shall deal more fully with this matter in another paper, that the maximum durability towards attack by water was also found in the 20 per cent. Na_2O series when the boric oxide content lay between 11 and 14 per cent.

In the second series, with 10 per cent. Na_2O, the glass with the highest annealing temperature was also the hardest of the series when worked in the blowpipe. This is to be expected in view of the dependence of annealing temperature on the viscosity.

Another glass which was particularly hard and resisted the action of the file was glass No. 620, containing silica 65, sodium oxide 5, boric oxide 30. The annealing temperature of this glass was 575°, but whether or not this corresponds with a maximum we cannot say, as owing to the instability of most of the glasses of this series we have not proceeded with their detailed examination.

Auerbach's measurements * do not indicate any specially note-worthy effect of boric oxide on hardness, but in view of our results and the known hardness of modern borosilicate glasses, the subject is worth closer investigation.

The Loss of Boric Oxide during the Melting Operations, and Pot Attack.

It is well recognised by glass manufacturers who make boro-silicates containing a considerable proportion of boric oxide and especially those who make miner's lamp glass that a distinct amount of boric oxide has to be added to the batch in excess of that which is required to be present in the finished product. The fuming of a pot of glass for miner's lamps is continuous when the stopper is taken down. We ourselves observed this fuming, especially with the glasses containing the higher proportions of boric oxide, for example, those with 40 per cent. B_2O_3.

This loss of boric oxide is clearly indicated from the results of the analyses contained in Table IV.

In the case of the glasses with 20 per cent. sodium oxide the loss from the 5 per cent. boric oxide glass was about 10 per cent. of the whole. From the glass to which 10 per cent. had been added there was a loss of about 13 per cent. of boric oxide and a still bigger loss from that to which 13·4 had been added. All these glasses had remained in the pot for twenty hours.

At the other end of the scale the loss at first sight would not appear to be so great. Actually, however, the rate of loss would probably be much greater. For example, in the case of glass No. 608, to which 45 per cent. of B_2O_3 was added, the total loss was between 6 and 7 per cent. of the original, but in this case the glass was worked out three hours after the batch was charged in, so that the relative loss was much greater. In the glass which was melted and worked out in two hours, there is no big discrepancy

* Hovestadt's *Jena Glass* (trans. by A. and E. Everett), Macmillan, 1902, p. 178.

TABLE IV.

Analyses of the Sodium Boro-silicate.

Glass No.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	B_2O_3.	Total.	Time in pot (hours).
600	79·84	0·69	0·11	0·12	tr.	19·46	—	} 100·22	22
Calc.	78·89	0·13	0·02	0·02	—	20·94	—		
601	74·22	0·93	0·14	0·14	tr.	19·78	4·46	} 99·67	20
Calc.	74·03	0·12	0·02	0·01	—	20·85	4·97		
602	71·56	1·00	0·08	0·10	tr.	18·76	8·28	} 99·78	20
Calc.	69·21	0·11	0·02·	0·01	—	20·73	9·92		
603	68·39	1·01	0·09	0·12	tr.	18·92	11·34	} 99·87	20
Calc.	66·22	0·11	0·02	0·01	—	20·83	13·31		
604	64·72	0·72	0·06	0·14	tr.	19·95	14·45	} 100·04	5½
Calc.	64·46	0·11	0·02	0·01	—	20·60	14·80		
605	61·28	0·74	0·08	0·11	tr.	18·93	18·84	} 99·98	7
Calc.	59·40	0·10	0·02	0·01	—	20·60	19·87		
606	50·04	0·78	0·05	0·08	tr.	20·36	28·83	} 100·14	2
Calc.	49·67	0·08	0·02	0·01	—	20·31	29·92		
607	35·22	0·84	0·07	0·16	tr.	23·71	39·99	99·99	3
608	32·23	0·84	0·07	0·22	tr.	23·08	43·70	} 100·14	3
Calc.	34·53	0·06	0·01	0·01	—	20·15	45·24		
610/2	74·91	0·89	0·05	0·10	tr.	11·26	12·45	} 99·66	12
Calc.	74·67	0·12	0·02	0·01	—	10·10	15·09		
609/6	70·75	0·82	0·07	0·10	tr.	9·79	18·71	} 100·24	12
Calc.	69·74	0·11	0·02	0·01	—	10·13	19·99		
611/2	67·18	0·88	0·07	0·13	tr.	10·13	21·81	} 100·20	12
Calc.	64·42	0·10	0·02	0·01	—	10·51	24·93		
612/2	61·94	0·84	0·11	0·14	tr.	11·19	25·82	} 100·04	12
Calc.	59·74	0·10	0·02	0·01	—	10·16	29·97		
613/2	57·87	0·98	0·09	0·09	tr.	9·55	31·26	} 99·83	12
Calc.	54·54	0·09	0·02	0·01	—	10·53	34·81		
614/2	52·11	0·89	0·11	0·10	tr.	10·34	36·17	} 99·71	12
Calc.	49·58	0·08	0·02	0·01	—	10·52	39·79		
615/2	46·30	0·80	0·10	0·08	tr.	10·44	42·33	} 100·05	6
Calc.	44·61	0·07	0·02	0·01	—	10·53	44·76		
616/2	41·29	0·80	0·10	0·13	tr.	11·49	46·07	} 99·88	4½
Calc.	38·90	0·06	0·02	0·01	—	12·22	48·79		

between the calculated and ascertained compositions, although even here loss of boric oxide evidently occurred.

On comparing the calculated and the observed compositions. there are seen to be two or three cases in which the sodium oxide in the glass is greater in amount than was supposed to have been added. It was known that the borax samples used varied in their water content and although most of them were checked, all were not. Probably to incorrect batch composition in this sense the discrepancies are to be attributed.

In most cases there is not only a very definite loss of boric oxide,

but also one of sodium oxide, whilst the silica is often 2 or 3 per cent. greater than in the batch. When the glass contains about 60 per cent. or less of silica, much of the observed increase is probably due to the solution of pot clay, corresponding with the increased alumina absorbed from the same source. Loss of B_2O_3 and of Na_2O must in themselves materially tend to increase the silica content of the glass.

The amount of pot attack would, from the figures relating to the percentage of alumina and iron oxide, appear to remain fairly constant. Here again, however, the time of standing in the pot was decreasing rapidly down the series and the rate of corrosion must obviously have been increasing. It may be noted that those glasses which were melted and worked out in three or four hours could be obtained colourless, whilst those which stood for a considerable period developed various depths of brown colour. In a number of cases a striking red colour was found existing particularly in the layer of glass adjacent to the bottom of the pot. The precise relationship between the iron oxide content and colour in this case has yet to be determined.

The Production of Opalescence in the Boric Oxide Glasses.

In glasses containing a high proportion of boric oxide there was a distinct tendency to produce opalescence, varying from a slight bluishness or smokiness to a very definite milkiness. This opalescence was produced either as the result of reheating or of slow cooling. The glasses which showed this phenomenon were those having the following approximate compositions :

SiO_2.	Na_2O.	B_2O_3.
50	10	40
45	10	45
40	10	50
55	5	40
50	5	45
60	5	35

No opalescence was observed in any of the glasses containing 20 per cent. of sodium oxide, but only in those where the sodium oxide was 10 per cent. or less and the boric oxide 40 per cent. or more.

Some experiments are being made to study this production of opalescence a little more fully.

The General Durability of the Boric Oxide Glasses.

The addition of boric oxide to a glass has quite definitely been proved to bring about an improvement in the durability. It is

clear, however, that such improvement only holds good within a certain range; for we found, indeed, that within a few days a number of the glasses containing a large proportion of boric oxide became covered with a white, flaky surface imparting to the glass a soapy feel. The glasses which showed this behaviour were as follows :

Approximate composition.

No.	SiO_2.	Na_2O.	B_2O_3.
600	80	20	0
607	40	20	40
608	35	20	45
614	50	10	40
615	45	10	45
617	55	5	40
618	50	5	45
619	60	5	35

Of these glasses, No. 617 was observed to show surface decomposition within seven hours after being worked and 618 and 619 after twenty-four hours. No. 606 exhibited a very slight film after four months and the two adjacent members of the series, 607 and 608, whilst somewhat inferior and are included in the above list, were no more marked in four months than 617 in a few days.

It is therefore evident that the lack of durability is not to be associated directly with the amount of sodium oxide present but rather with the proportion of boric oxide. Rapid disintegration with the 40 per cent. boric oxide glasses was most definitely observed when only 5 per cent. of sodium oxide was present.

We shall return to the subject of the effect of boric oxide on the durability of glass in a further paper.

Summary.

1. Meltings have been carried out on three series of sodium borosilicate glasses containing approximately 20, 10, and 5 per cent. of sodium oxide. In each series the amount of sodium oxide was maintained approximately constant, whilst the silica and boric oxide portions were varied. In the first series, nine glasses were prepared containing from 0 to 45 per cent. of boric oxide; in the second series, eight different meltings were made and the amount of boric oxide ranged from 15 to 50 per cent.; in the third series, involving seven meltings, the range of boric oxide tested was from 20 to 45.

2. It was found throughout the range that homogeneous glasses could be prepared and there was no segregation in layers of different composition.

3. Boric oxide beyond a certain amount does not make for durability but the reverse. The glasses containing 40 to 45 per cent. of boric oxide in both the 10 and 20 per cent. sodium oxide series and from 35 to 45 per cent. of boric oxide in the third series (with 5 per cent. of sodium oxide) all developed a white film or coating after a week or two, some of them within a day or so. The most readily disintegrated glasses were those containing only 5 per cent. of sodium oxide, so that the decomposition must be associated, not with that oxide, but with the boric oxide.

4. With increasing boric oxide in each series and diminution in the amount of silica, the rate at which melting and refining occurred increased rapidly. In the case of the 20 per cent. sodium oxide glasses, the increase in the rate of melting progressed steadily throughout the series; but in the 10 per cent. sodium oxide series the improvement was not continuous, and appeared to occur in steps.

5. Soda ash has considerably greater fluxing action than has borax or boric oxide. This conclusion is based on a large number of observations with the sodium borosilicates.

6. The rate of change of viscosity increases very greatly as silica is substituted by boric oxide. Several of the glasses containing large proportions of boric oxide were too fluid for working at temperatures between 1000° and 1100° or even less, but on the other hand set so rapidly when gathered that working was impossible.

7. Considerable loss of boric oxide through volatilisation was found to occur. The amount of loss depended both on the proportion of boric oxide present in the glass and on the time of standing in the pot.

8. All the glasses of the 20 and 10 per cent. series examined could be worked readily in the bench blowpipe and showed no signs of devitrification.

9. Glasses of the 5 per cent. sodium oxide series containing 35 to 45 per cent. of boric oxide and in the 10 per cent. series containing between 40 and 50 per cent. of boric oxide developed opalescence either on reheating or slow cooling.

10. Several of the glasses containing a high proportion of boric oxide developed seed or bubbles in abundance when gathered from the pot, although initially the glass was free from seed.

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DISCUSSION

MR. A. L. MARDEN, referring to the fluxing effect of boric oxide, said that some time ago they were melting a quantity of soda

glass, and met with difficulty in getting it founded on time. They were recommended to substitute 4 per cent. of soda by 4 per cent. of boric oxide. They did so, but found no improvement at all in the founding time.

Mr. W. Butterworth inquired how much soda there was in the glasses for which the corrosion with water was a minimum.

Prof. Turner said he was very interested in the confirmation which Mr. Marden's statement provided of the over-rated fluxing effect of borax. In reply to Mr. Butterworth, the amount of sodium oxide in each series of glasses was kept as nearly as possible constant, so that its influence was cut out in comparing the various glasses in the same series.

VI.—*The Influence of Boric Oxide on the Annealing Temperature of Borosilicate Glasses.*

By S. English, M.Sc., and W. E. S. Turner, D.Sc.

It is well known that the borosilicate glasses of which present-day chemical glassware is made need a comparatively high temperature for their annealing. Thus, we have previously found that a glass of percentage composition SiO_2 64, Al_2O_3 10, CaO 7, B_2O_3 7, Na_2O and K_2O 11·5 had an annealing temperature of 630°. A second glass examined by us containing SiO_2 70, Al_2O_3 10, ZnO 2, B_2O_3 7, Na_2O and K_2O 8—9, required an annealing temperature of 635°. On the other hand, a somewhat similar glass but with only 2 per cent. of boric oxide and several per cent. more of alkaline oxides could be annealed at a temperature of 570°.

These observations * led us to the view that boric oxide appeared to raise the annealing temperature in borosilicate glasses. Moreover, of the other major constituents of these glasses, we have subsequently shown that a very high proportion of silica does not raise the annealing temperature unduly. Thus, the sodium silicate containing 82·8 per cent. of silica and 17 per cent. Na_2O had an annealing temperature of only about 522°. Nor can the high annealing temperature of chemical glassware and other borosilicates be ascribed to alumina, as we have shown that the glasses containing considerable proportions of this oxide are fairly readily annealed.

We were further led to regard the boric oxide as being probably the chief cause of the high annealing temperature of commercial borosilicates as a result of examining miner's lamp glass. A sample of

* English and Turner, this Journal, Trans., 1918, 2, 90.

percentage composition SiO_2 65, B_2O_3 23, Al_2O_3 2, Na_2O and K_2O 10, was found to require an annealing temperature of 585—590°. This temperature is moderately high, but distinctly lower than that needed by the more complex borosilicates to which we have referred above as being employed for many types of chemical glassware; and this lower temperature, despite the much higher boric oxide content, might seem to cast doubt on our initial idea of boric oxide raising the annealing temperature.

The explanation is most probably forthcoming on the basis of the results recorded below.

In the experiments now recorded measurements have been made of the annealing temperatures of two series of sodium borosilicates,

The annealing temperatures of the sodium borosilicate glasses.
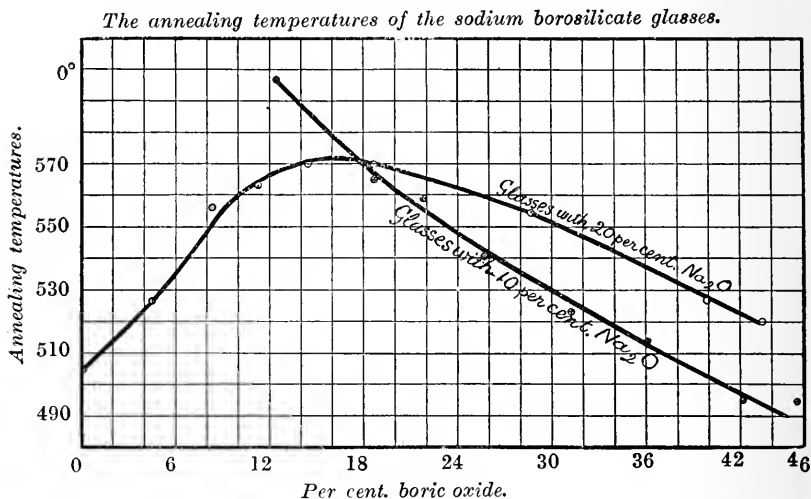
Fig. 14.

a description of which has been given in the preceding paper. The annealing temperatures were determined on samples of rod with plane polished ends, as used in previous investigations, and the same conditions of experiment were observed as previously. The results are stated in the tables below and also in graphical form in the figure.

When examining the curves shown in the figure, it should be remembered that owing to divergences of composition from the precise 20 or 10 per cent. Na_2O, the glasses are not strictly comparable. The results, however, do fit the curves very well.

The results clearly indicate in the case of the glasses with approximately 20 per cent. of sodium oxide that, as silica is substituted by boric oxide, the annealing temperature rises, reaches a maximum at about 16—17 per cent. of the oxide and then steadily falls.

TABLE I.

Annealing Temperatures of Sodium Borosilicates.

A. *Glasses containing approximately* 20 *per cent.* Na_2O.

Glass No.	Per cent. B_2O_3.	Annealing Temperature.
600	0·0	505°
601	4·46	527
602	8·28	557
603	11·34	563
604	14·45	570
605	18·84	570
606	28·83	555
607	39·99	527
608	43·70	521

B. *Glasses containing approximately* 10 *per cent.* Na_2O.

Glass No.	Per cent. B_2O_3.	Annealing Temperature.
610/2	12·45	597°
609/6	18·71	565
611/2	21·81	559
612/2	25·82	541
613/2	31·26	523
614/2	36·17	514
615/2	42·33	495
616/2	46·07	495

In the case of the glasses with 10 per cent. sodium oxide, the values for the glasses examined fall continuously. All the evidence we possess, however, suggests that had it been possible to obtain glasses containing between 0 and 12 per cent. of boric oxide in this particular series (which would have meant a high silica content), a maximum would have been recorded. This appears highly probable from the fact already mentioned that sodium silicate with 82·8 per cent. of silica and 17 per cent. sodium oxide can be annealed at a temperature of 522°. It is therefore very probable that the annealing temperature of the glass with 12·43 per cent. of boric oxide, namely, 597° lies somewhere near a maximum point in the series. At a later stage we hope to melt a series of glasses at a higher temperature than 1400° and to test this portion of the range which for the moment is unmapped.

The two following sets of comparisons are also of interest :

	Approximate composition.			Annealing temperature.
	SiO_2.	B_2O_3.	Na_2O.	
I.	64·66	14·45	19·95	570°
	67·10	21·81	10·26	542
	(65·0	30·0	5·0)	575
II.	49·88	28·83	20·36	555
	57·80	31·26	9·55	523
	(65·0	30·0	5·0)	575

The actual compositions depart, as so often is the case of glasses, from those intended, and precise comparison is not possible. In series I, the silica content is approximately constant at about 65, whilst in II the boric oxide percentage is in the neighbourhood of 30. The third glass in each of the two sets belongs to a series of glasses with 5 per cent. Na_2O only. As most of this series were unstable, their properties have not been examined and the analyses have not been carried out.

It will be seen that substitution of soda by boric oxide in the first, and of soda by silica in the second, does not have a progressive influence on the annealing temperature, a minimum appearing in each case.

The discussion of the meaning of the maximum point we propose to reserve to another paper, as maxima have been observed in the values of several other properties.

Attention has already been directed in the preceding paper to the fact that maximum hardness as tested by resistance to cutting with a file, occurs in the glasses with 20 per cent. sodium oxide at the point near to which the maximum annealing temperature is found. The glass of the 10 per cent. sodium oxide series which was found to be hardest when worked in the blowpipe was that with the highest annealing temperature. This connection is to be expected in view of the relation between annealing temperature and viscosity.

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VII.—*The Analysis of Glasses Rich in Boric Oxide.*

By VIOLET DIMBLEBY, B.Sc., and W. E. S. TURNER, D.Sc.

DURING the manufacture of boric oxide containing-glasses, slow volatilisation occurs, varying with the temperature and with the concentration, as has been demonstrated in a previous paper.*

The time taken during the fusion in an analytical operation, however, is only a matter of minutes, and the temperature is distinctly lower than in the manufacture of the glass. Nevertheless, owing to the excess of sodium carbonate used, the melt is very fluid and permits volatilisation sufficient to produce a distinct

* Dimbleby, Hodkin, Parkin, and Turner, this vol., p. 57.

source of loss. This we found when analysing the sodium boro-silicates of high boric oxide content.

It seemed to us, after an examination of all the records of boric oxide glasses carried out in this laboratory, that if the glass did not contain much more than 10 per cent. of boric oxide that quantity could be determined quite accurately. This being so, it also seemed reasonable to suppose that if we could, for the purpose of analysis, so treat a glass of high boric oxide content as to reduce the boric oxide to about 10 per cent., then the analytical operations should be capable of accuracy.

The procedure we have adopted regularly in the analysis of boric oxide glasses which do not contain zinc or other elements likely to interfere with the direct determination has been set out in a previous paper from this Department,* and is based on Wherry's method. It involves the use of 0·5 gm. of the glass and 3 gms. of sodium carbonate with which it is fused. We shall refer to this method later as the original method.

In the modification which we propose and have actually adopted, pure silica is also added and the amount of the glass reduced as the boric oxide content increases. The two alterations, namely, the reduction in the amount of glass used and the amount of silica added, are adjusted so as to give, before fusion with sodium carbonate, the equivalent of a glass containing approximately 10 per cent. of boric oxide. The weight of sodium carbonate employed for fusion has been maintained at 3 gms.

The following table (Table I) shows how very different are the results obtained by the new method as compared with the original. The loss of boric oxide in the former is seen to be very great; so great as to make the determinations valueless. The difference was greater as the concentration of boric oxide increased.

<center>TABLE I.</center>

Glass No.	Per cent. B_2O_3.	
	Original method.	New method.
606	24·73	28·78
613	28·41	31·21
615	34·30	42·24

The results of a number of determinations in which the conditions were varied are set out in Table II.

* J. D. Cauwood and T. E. Wilson, this Journal, TRANS., 1918, 2, 246.

TABLE II.

Experiments on the Determination of B_2O_3 *under Varying Fusion Conditions.*

Glass No. 616.

No.	Wt. of glass.	Wt. of silica.	Wt. of sodium carbonate.	Time of fusion.	Per cent. B_2O_3 found.
1	0·5 gm.	0	3 gms.	8 mins.	45·60
					45·71
					44·38
					45·31
2	0·1 ,,	0	3 ,,	6 ,,	44·86
					45·45
					45·60
3	0·4 ,,	0·1 gm.	3 ,,	6 ,,	45·53
4	0·3 ,,	0·2 ,,	3 ,,	6 ,,	45·23 *
					45·54 †
5	0·2 ,,	0·3 ,,	3 ,,	7 ,,	45·98
6	0·1 ,,	0·4 ,,	3 ,,	12 ,,	45·90
					46·05
7	0·1 ,,	0·5 ,,	3·5 gms.	12 ,,	45·82
					45·72

* Ppt. of silica not redissolved in order to extract traces of B_2O_3.

† Ppt. of silica twice dissolved.

For the glass in question, which contained approximately 46 per cent. of boric oxide, we concluded that 0·1 gm. of the glass was the most suitable amount to use together with either 0·4 or 0·5 gm. of silica. Much the same result, however, was obtained when 0·2 gm. of glass and 0·3 gm. of silica were employed.

It will be seen that when 0·1 or 0·5 gm. of the glass was fused with sodium carbonate alone the results are distinctly variable, even when, after the experience with glasses 606, 613, and 615, special care was taken with the fusion.

The addition of silica means an increase in the bulk of the precipitate which is obtained when calcium carbonate is added at a later stage of the analysis to neutralise the hydrochloric acid, and there is a risk of a small loss of boric oxide if the residues of this oxide are not extracted from the precipitate. The precipitate was, in fact, re-dissolved and re-precipitated and a second solution and re-precipitation also carried out. The difference in the result through this treatment is shown in the set of experiments No. 3 in Table II, the error involved being about 0·6 to 0·7 per cent.

In order to test the accuracy of our results obtained by the modified method, we have available for the purpose the complete analyses of the various glasses. In Table III, therefore, we state the total oxides found by analysis in the glass, the actual boric oxide determined by analysis, and the amount of boric oxide which

would have been found if it had been determined merely by difference.

TABLE III.

Glass No.	Total oxides by analysis.	Total oxides, not including B_2O_3.	B_2O_3 by diff.	B_2O_3 by expt.
601	99·67	95·21	4·79	4·46
602	99·78	91·50	8·50	8·28
603	99·87	88·53	11·47	11·34
604	100·04	85·59	14·41	14·45
605	99·98	81·14	18·86	18·84
606	100·14	71·31	28·69	28·83
607	99·99	60·00	40·00	39·99
608	100·14	56·44	43·56	43·70
609	100·24	81·53	18·47	18·71
610	99·66	87·21	12·79	12·45
611	100·20	78·39	21·61	21·81
612	100·04	74·22	25·78	25·82
613	99·83	68·57	31·43	31·26
614	99·71	63·46	36·46	36·17
615	100·05	57·72	42·38	42·33
616	99·88	53·81	46·19	46·07

The boric oxide determined by difference bears the full weight of the accumulated errors on the various other oxides. Most of the analyses, however, have been thoroughly checked and the duplicate results agree very closely. The results have also been calculated on the composition of the glass after the latter has been dried at 110° and heated at about 400° to drive off occluded moisture.

It will be recognised from the table that the analytical values determined as described must be regarded as accurately representing the boric oxide content of the glasses, and we can therefore recommend with confidence the procedure outlined.

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    THE UNIVERSITY, SHEFFIELD.

A Study of the Melting and Working Properties of Boric Oxide Glasses, with special reference to the Sodium Borosilicates.

By Violet Dimbleby, B.Sc., F. W. Hodkin, B.Sc., M. Parkin, M.Sc., and W. E. S. Turner, D.Sc.

Discussion.

Mr. E. A. Coad-Pryor (*communicated*) : The absence of precise information with regard to borosilicate glass has been, in the past, a great hindrance to all who have to work with glass of this type, and the authors are to be congratulated on this paper, which, I hope, is but a preliminary to a fuller discussion of the borosilicate glasses.

With regard to the recurrence of seed, I can confirm this phenomenon in works practice, with glasses comparatively low in boric oxide, that is, from 10 to 15 per cent. I am not quite sure that I agree with the authors' belief that the seed is due principally to the volatilisation of boric oxide. I have, in certain glasses, observed seeds coming out during the cooling, and although the reason for this is obscure, I am inclined to think that the fact is fairly well established. The matter could be settled by observing whether, after a reboil has occurred and the seed has been plained off, this glass is now less liable to give a reboil than it was initially. Making due allowance for the decrease in boric oxide content, with a fairly high boric oxide glass there should still be a tendency to reboil after repeated plainings. If, on the other hand, it is due to supersaturation, the reboiling tendency should be greatly reduced.

I have found, in small scale melts, violent reboil in glasses free from boric oxide or any constituent more volatile than soda or silica, but have never followed this up very closely. It has been stated, however, I think by Sir Herbert Jackson, that certain glasses after the reboil has disappeared and the glass has been plained show a remarkable difference in properties as compared with the glass before the reboil, a difference greater than can be accounted for by volatilisation of one of the constituents.

A curious point which one notices in large scale melts is the apparent recurrence of striæ. This may be due merely to the formation of a skin and the difficulty of clearing off the scum before gathering the proofs. Examining proofs which were badly striated, I have been rather intrigued to notice that no strain was observable in the polariscope. With bad striation, one nearly always notices

strain due to the difference in the coefficient of expansion between the cord and the glass. If the striation consists merely of glass low in boric oxide, one would expect to notice big differences in the coefficient of expansion, since boric oxide reduces so exceptionally the coefficient of expansion of glass.

The authors comment on the comparative fluxing power of soda and boric oxide, suggesting that soda is more potent as a flux than boric oxide. Whilst this is so in many cases, it appears probable that in many others the reverse will occur. Probably with only soda, boric oxide, and silica in the batch, the composition which will melt quickest at any given temperature is that which corresponds with the ternary eutectic between the three components; the further away from that eutectic, the longer the batch will take to melt, in all probability. For example, it will be noticed that with 40 per cent. boric oxide, a glass containing 10 per cent. of soda takes very much longer to plain than a glass containing 5 per cent. soda, and yet one would not suggest that silica is a better flux than soda.

In excessively acid glasses, soda would naturally be a potent flux, but with the average glass one would expect boric oxide to be more chemically active. It is extraordinarily difficult to dissolve a lump of dead burnt or fused zirconia or alumina in fused soda, but it will dissolve reasonably quickly in fused borax.

With regard to the durability, I rather gather from the paper that the 20 per cent. Na_2O series gave a maximum durability. The wording in the paper is a little vague, and I shall be glad to know if I am correct in this assumption.

It would be interesting to know if analyses were made of Mr. Cousen's meltings of the silica and boric oxide. One would expect to find that the two layers had the same composition in all the melts, and the upper layer was, presumably, a saturated solution of silica in boric oxide.

Mr. W. Butterworth, jun. : Our limited experience all goes to corroborate that of the authors. We have found boric oxide glass with more than 12 per cent. of boric oxide to have a small working range. It is very resistant to abrasion. It fumes slightly when very hot; the volatilisation, however, is chiefly evident in the corrosion of the top of the pots, which often becomes shaped inside like horse's ribs. It easily becomes slightly opalescent, although the boric oxide content is only about 12 to 14 per cent. It is not specially liable to seeds and bubbles, but is so to cords and waviness, indicating a lack of homogeneity. The temperature of the metal has to be very well sustained right through the working out process. I was interested to note the remark as to the instability of glasses with high boric oxide content. I had suspected this. Is it not

the fact, however, that many of the fluxes used in the application of stained glass colours have a very large proportion of boric oxide and are yet quite stable?

MR. F. W. HODKIN : Mr. Coad-Pryor's remarks concerning the recurrence of seed are very interesting. I have no definite reason to offer which would account for the recurrence of seed, but the fact that the introduction of a blowing iron into a distinctly cooled pot of glass free from seed caused the appearance of many fine bubbles might favour the idea of supersaturation. On the other hand, some experiments made with the object of eliminating gas in solution by raising the temperature did not give results which fit in with the supersaturation theory. One pot of glass in which the seed appeared was actually reheated from about 1000° to 1300° and retained at that temperature for four hours, but no difference whatever was noticed in the amount of seed present. With regard to the boil occurring in small scale meltings, I can confirm this experience, particularly with regard to glasses made from salt-cake. Further, the glass remaining in the pot, after the boiling, was distinctly more viscous than before.

PROF. W. E. S. TURNER thanked Messrs. Coad-Pryor and Butterworth for their valuable contributions to the discussion. Some of the questions raised by Mr. Coad-Pryor require that further investigation shall be made before they can be answered. Indeed, the paper is full of suggestions for further research. The subject of the cause of the seediness of these glasses is a problem in itself. One might argue that if the seediness were due to gases in supersaturated solution, then the boric oxide glasses should evolve gases when melted under reduced pressure rather more freely than other types. The results of Washburn, Footitt, and Bunting, however, showed that a borosilicate with 10 per cent. of B_2O_3 evolved less gas than any of the three other types of glass tested. It would be very interesting to carry out some measurements of the gases evolved as the melting operation proceeded. Mr. Coad-Pryor is quite right in directing attention to the fact that the fluxing effect of a substance must have reference to other components of the mixture, and contradictions are likely to be found in any attempted rough-and-ready rule. Nevertheless, the evidence adduced has, we consider, been sufficient to show that the ordinary works view of the fluxing value of boric oxide must be modified.

The durability of the sodium borosilicates towards the action of water does increase to a maximum and then rapidly declines. We shall deal more fully with this subject at a later date. In the 20 per cent. sodium oxide series, the maximum durability occurred when the percentage of boric oxide was in the neighbourhood of 12—13.

In reply to the question as to whether analysis was made by Mr. Cousen of the layers obtained when boric oxide and silica were fused, this was done only in the case of the upper layer from the melting of equal parts of silica and boric oxide, this layer proving to have 41·85 per cent. of silica.

In regard to Mr. Butterworth's remarks, these give, from everyday observation, valuable confirmation of some of our own tests, and go, indeed, beyond them.   Thus, we have not observed the curious corrosion markings on the roof of the pot referred to by Mr. Butterworth, but this is possibly due to the fact that in our experiments the pots were in use only for a few days.   Boric oxide is, as Mr. Butterworth observed, an important component of many glazes and enamels.   The disadvantages of boric oxide in this connection do not appear to have been as fully appreciated as the advantages.   Recently, H. F. Staley, in a thorough investigation of the resistance of enamels to acids, drew the conclusion that boric oxide is by no means a desirable constituent from the point of view of obtaining durability.

VIII.—*Organising for Production from Pot Furnaces.*

By W. W. WARREN, A.M.I.C.E., A.M.I.E.E.

Introduction.

THE subject of this paper will be approached with the aid of experience gained at the Lemington Glass Works, where methods for producing electric lamp bulbs from pot furnaces are modelled on those which obtain in Germany and Holland.   Whilst it is admitted that in the appraisal of those who speak of the " art of glass making " the manufacture of bulbs is considered low in the scale of that art, yet, it is a business which, because the article is light, magnifies possible sources of waste, both waste of time and waste of metal.   In order to work out a pot of metal in a given time, small gatherings must be numerous and follow quickly on one another.   The waste of metal in the moils of light articles generally bears a larger proportion to the saleable product than is the case with heavy articles.   These considerations demand close control of both system and workmanship.

Comparing the present works practice at Lemington with that of 1918, when the output of hand-made bulbs was approximately

similar in number and weight, there are now only 20 pots in com-
mission as against the 70 pots at the earlier date.   This intensifying
of production per pot has effected an enormous saving of coal, and,
in a smaller degree, of pots, and of auxiliary labour.   In fact, fuel
costs are less than they were in pre-war times.   It must be re-
marked, however, that the furnaces shut down are direct coal-
fired furnaces, leaving the gas furnaces only in operation.   In
1918, four men worked at a pot, where there are now six; and
the time-table system of founding by night and working by day
was not so perfect as it is now.

Furnace Conditions.

Production on a satisfactory scale can never be achieved unless
the furnace design will permit of adequate temperature for rapid
melting, perfect and elastic control of the temperature, and the
uniform distribution of heat.   The function of a furnace is to
melt glass.   The time occupied in working out pots, cooling off pots
beyond the " plaining stage," and charging them with batch and
cullet should be regarded as operations, albeit necessary, which
reduce melting efficiency.   The endeavour to secure maximum
melting efficiency will usually direct the course to be taken to
achieve it.

There can be no question about the effect on production of the
metal being good, which is largely a matter of temperature con-
ditions.   Good metal at a temperature favourable to the high
rate production of good ware prevents mental irritation in the
glass-maker and secures an important factor affecting output.
Metal that is too hot, or that is not quite plain at the commence-
ment of the day, may easily affect the daily output to the extent
of 15 per cent., largely as the result of the adverse influence on
temperaments.

For most purposes circular gas furnaces, either regenerative or
recuperative, are to be preferred to those of rectangular shape.
They provide around the pots working spaces, the boundary lines
of which diverge outwards and furnish facilities for a larger number
of men, unless the inefficient method of working out alternate pots
be adopted.

Above a certain critical length, heat distribution in a rectangular
furnace is not so good as in one of circular design.   In respect of
heat distribution a circular recuperative furnace with central eye
is particularly satisfactory.   It is doubtful, however, whether this
type of furnace would constantly reach the high temperatures
necessary for melting glass nightly in covered pots; and, it has the
further drawback that it responds slowly to adjustments made to

raise the working temperature to that of melting, when pots are emptied and filled again. The recuperative furnace, however, gave the lead at Lemington in proving that it is possible to melt a lead batch in open pots.

The semi-circular or D-shaped furnaces which have been developed at Lemington Glass Works, whilst not efficient in fuel consumption on account of their large radiation surfaces, have an appreciable range of temperature control above that necessary for melting, the temperature rising quickly when set away for the found. The heat stored in the wall representing the straight line of the D is considerable and makes for uniform heat conditions. There are air regenerators only; the gas with its sensible heat going straight into the furnaces from the producers, which are contiguous.

Reverting to the statement that the function of a furnace is to melt glass, a pot furnace can never have as high a melting efficiency as a tank furnace. The nearest approach to such ideal conditions is attained in the pot furnace in which glass is melted for rolled plate, and the pots of metal are poured on to a table. In this case very little time is lost between successive meltings. When the metal has to be gathered, the glass blowers have to be provided with a minimum of eight hours' work a day; consequently, the problem is to melt in each pot per day the maximum possible amount of batch and cullet and to group the glass blowers, with due regard to the size of the ware that they have to make, so that the pots are just worked out in the allotted time.

Before the system of founding by night and working by day was adopted at Lemington, and four men to a pot were the limit to the number in a group, it was not unusual for the working period to extend over 12 to 16 hours. Under the present system, a group consists of six blowers, sometimes eight, and the rings are invariably on the bottom of the pots at 5 o'clock, except in those from which metal is gathered for the smallest types of bulbs. Twelve cwt. of batch and cullet in the proportion of three of batch and four of cullet may easily be melted every night and be ready for the 8 o'clock start. The maximum temperature of the furnaces when using covered pots is 1,500°, and when using open pots 1,400°. During the working period the temperature is lowered to 1,100° inside the pot.

It is sometimes stated that founding by night and working by day is practicable only in the case of a lead batch. That statement, however, should not pass unchallenged. If a lead batch can be melted in a covered pot, the use of an open pot should facilitate the melting of harder glasses. Moreover, the design and con-

struction of pots to withstand higher temperatures afford a wide field for experiment.

A pot which has been tested with a fair measure of success from the point of view of withstanding high temperatures is shown
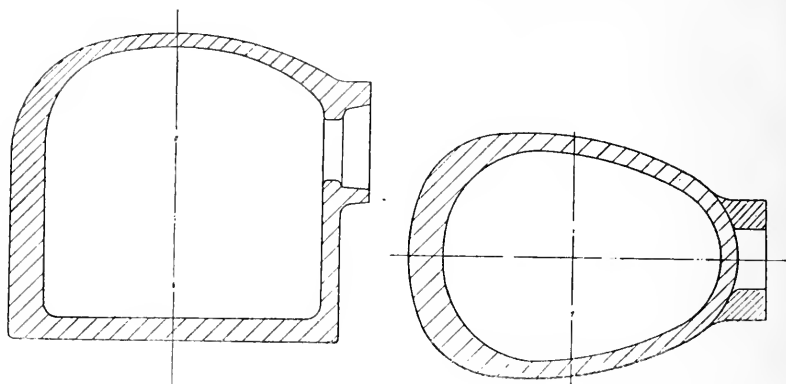
FIG. 1.

in Fig. 1.   The back was made thicker and the front thinner than in standard practice.   Fig. 2 shows a pot with strengthening bands of clay round the back.   These bands, however, melted and proved a failure.   Perhaps as a strengthening device, ribs on the
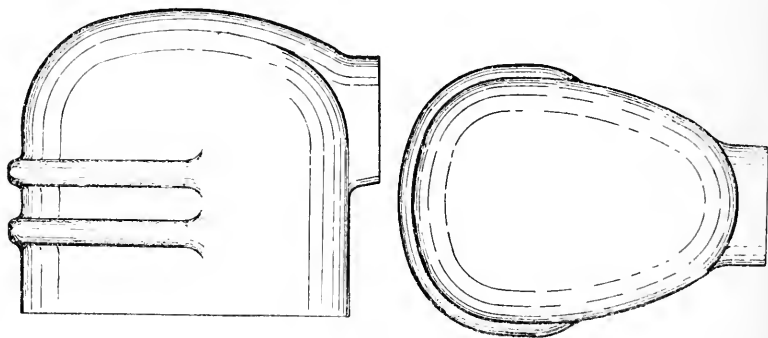
FIG. 2.

inside of the back portion of a pot, as indicated in Fig. 3, where they would be cooled by the glass, would be found satisfactory.

Fig. 4 depicts a pot with a corrugated wall which is being tried as an experiment to overcome troubles as the result of differences of temperature.   The idea is borrowed from the province of mechanical engineering.
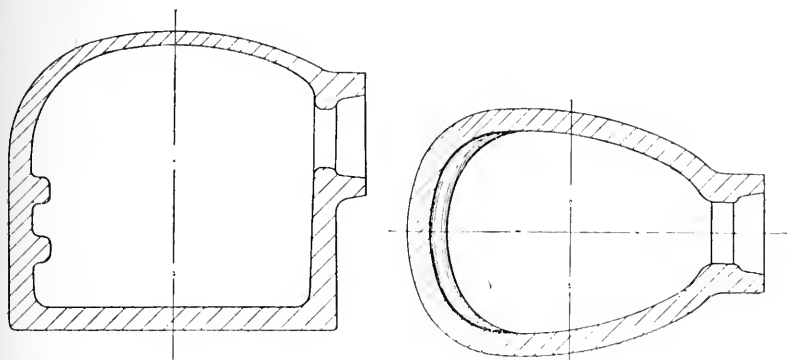
Fig. 3.
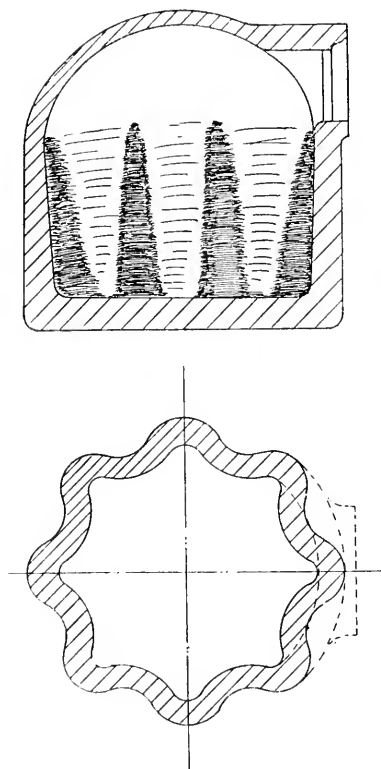
Fig. 4.

As a suggestion, may not borosilicate glasses be melted in revolving pots. Temperature conditions would be more uniform in the pot; and, moreover, no portion of the wall of the pot would constantly be at a dangerously high temperature. Consequently the temperature of the furnace could be raised above 1500°.

Not the least advantages of working to a time-table in the matter of founding and working during definite periods are : (a) the responsibility devolves on the producer and furnace men to have metal ready in time for their co-workers; (b) the work of mixing, pot-filling, and all operations subsidiary to glass-making run smoothly in an appointed groove. In fact, this method imbues everyone in the works with a spirit of efficiency.

The Output Balance of Pots.

The smaller the article for which metal is gathered, the higher the percentage of waste in moils. A pot originally charged with 1200 lb. of batch and cullet may prove, after having been worked out, to have produced :

Saleable ware	450 lb.
Skimmings and moils	570 ,,
Remaining in pot	120 ,,
Unaccounted for (volatilisation)	60 ,,

It is possible, when making bulbs, to control the weight of the moil to one-third of the weight of the article; consequently, in the above example, there is a potential increase of output (allowing 30 lb. for skimmings) of more than 50 per cent. To obtain this increase of output, steps would first have to be taken to reduce the weight of the moils, partly—where possible—by reducing the diameter of the noses of the irons, and partly by strict supervision over workmanship.

The importance of checking the output of pots should be realised, and figures taken out daily to inform the management of variations in pot efficiency. At Lemington, the costs are based on the number of pots in commission, and the number of bulbs of any type which can be obtained out of a pot are known. Prices are therefore calculated in such a way that, should the whole factory be thrown over to making one type of bulb throughout, the financial results would be the same as when any combination of types is in progress.

The Grouping of the Glass Blowers at Pots.

Obviously, to work out a full pot of metal when making bulbs weighing 4 lb. per 100 bulbs will require both a faster rate of working per man and a larger number of men in a group than when bulbs weighing 12 lb. per 100 are called for. The small

bulb may be made at the rate of 900 per man per day, and the group of blowers per pot to meet the requirements of an output per pot of 500 lb. should be 14. To provide working room for this number is impossible, so a compromise must be made by fitting in an unusually large bulb with the small one. The bulb weighing 12 lb. per 100 bulbs is satisfactorily handled by 6 blowers, each making 700 bulbs per day. For high rates of production per pot, open pots are more suitable than the covered variety, as they permit of the construction of a breast wall with a double working hole. By means of this arrangement, and by the provision of suitable platform facilities, two groups each of 6 men may be employed to a pot.

The U.S.A. Method.

Consider now the U.S.A. system of working shift work over 16 hours per day, and melting in pots of a melting capacity of 2,400 lb. of metal. This quantity of metal is made " plain " and is cooled off in the total time of 24 hours. The groups of glass-makers vary from eight—(four gatherers and four blowers)—to twelve (six gatherers and six blowers). When making bulbs at 12 lb. per 100 the group consists of eight men, each making at the rate of not more than 700 bulbs per shift of eight hours, and the time taken to work out the pot is 16 hours. The American pot melts twice as much metal as the Lemington pot; it takes 1·6 times as long to melt its charge, and three times as long to be worked out, owing to the fact that there is a cessation of work for eight hours during the twenty-four. The balance of quick production is, therefore, in favour of the Lemington method.

The Effect on Costs of Increasing the Production.

The reducing effect on the costs of bringing idle plant into commission and thereby increasing production is appreciated and needs no comment, but the similar effect obtained as the result of operating the running plant more efficiently is striking and worth closer inspection.

Take a concrete example whereby production is increased by limiting the size of moils and the increase is 50 per cent., as was shown possible by the example of an output balance of a pot. In the first column shown below are the relative costs of the various items for 1,000 bulbs of average weight at a certain output. In the second column are figures showing how those costs are affected by increasing the output as stated.

	Cost per 1,000 bulbs.	Cost per 1,000 bulbs 50 per cent. increased output.
Batch	13	13
Coal	5	4
Wages	45	37
Salaries		
Rent, rates, and insurance		
Depreciation		
Carriage		
Packing material	37	28
Pots		
Gas, electricity, and water		
Repairs (materials)		
Furnace repairs (wages)		
Sundries		
	100	82

Standing charges.
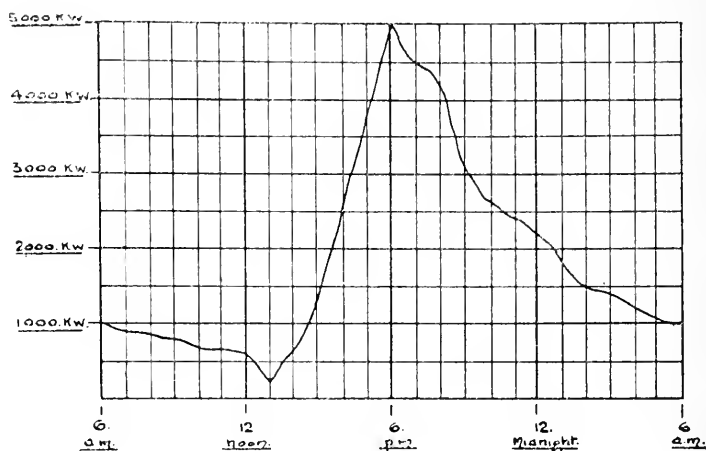
Fig. 5.

It will be noted that wages in the first column would have to be cut by more than 30 per cent. to bring about the result shown at the foot of the second column. This is a forceful argument to use with workmen when introducing methods contrary to tradition.

The elimination of waste, such as the moils represent, may be turned to advantage in the following ways :

(a) To meet increasing demand.
(b) To operate a minimum number of furnaces.
(c) To create a demand by cutting prices.

A classic instance of creating a demand by cutting prices is seen in the practice of electricity supply undertakings in selling

electrical energy for power purposes at a lower figure than for lighting uses.   In the early days of these undertakings it was their avowed purpose to supply electricity for lighting only, when their daily loads were similar to the curve, Fig. 5.   The problem was to flatten the curve, or load the plant and mains to the fullest possible extent so that overhead charges and running costs could be reduced to a minimum.   This was achieved by cultivating a demand for electrical energy for power purposes, which are generally of longer daily duration than lighting demands.

Suggested Improvement of Pot Furnace Practice.

In view of the practical demonstration of the possibility of ladling either lead or soda–lime glasses from pots, in which the glass is melted, into a tank, and the successful operation of the Westlake Bulb Blowing Machine in conjunction therewith, it would appear reasonable to expect to derive the full advantages of such practice if introduced into the domain of hand-made ware.

To fix ideas, assume that an 8-pot furnace, each pot having a capacity of 3,000 lb. of metal, and maintained at a constant melting temperature of 1,400° is operated in series with working tanks kept constant at a working temperature of 1,100°, the tanks to have ten boots or working holes with facilities for six blowers to work at each boot.   By employing three shifts, 180 blowers would be occupied and make in a week 500,000 bulbs of an average weight of 10 lb. per 100 bulbs.

From the time of commencing to charge a pot until the metal was ready to be ladled, 32 hours would elapse, and a further 2 hours would be occupied in ladling, making 34 hours in all.   In a week of seven days, approximately 120,000 lb. of metal would be available for transference to the tanks, a quantity which should leave ample margin for the estimated number of bulbs, and so bridge such contingencies as a broken pot, pot setting, etc.

The advantages of this scheme as compared with the present Lemington practice are shown in the subjoined table :

	Pot-tank combination.	Simple pot furnaces.
Number of pots	8	30
Life of pots	3 to 4 months	6 weeks
Fuel consumption	80 tons per week	90 tons per week
Life of tank	2 years	—
Cost of plant and buildings	Favourable	Unfavourable
Cost of moulds, irons, etc.	,,	,,
Temperature	Constant	Variable
Metal level	Fairly constant	,,
Interval between repairs to furnaces	5 years	2 years

The disadvantages are those attached to shift work and to ladling glass. The tanks would probably throw small stones, and blisters might be prevalent. There would be the further disadvantage common to all large units of plant when they go out for repairs, namely, the cessation temporarily of a large output; and the large unit is not so elastic in coping with a variable demand.

Fig 6 illustrates the suggestion and arrangement of a pot-tank furnaces.
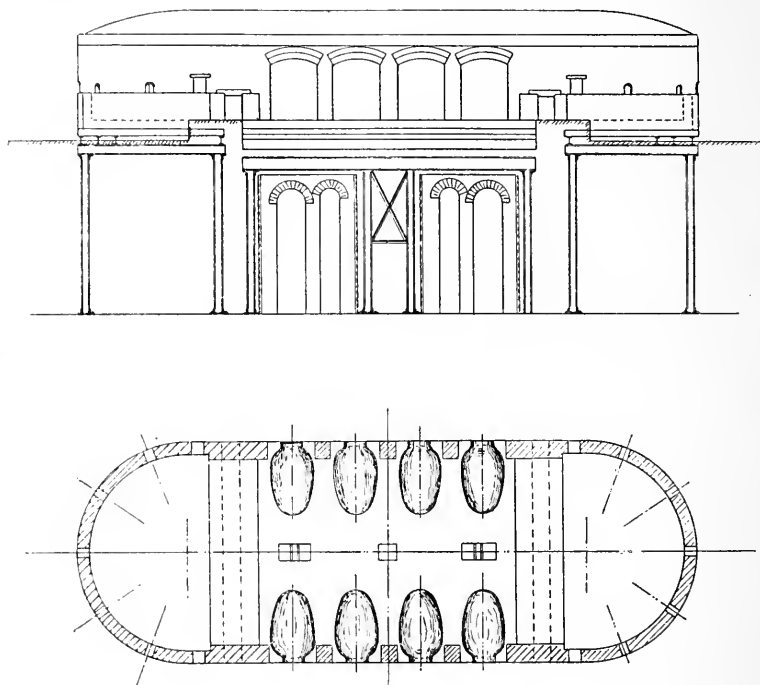
FIG. 6.

The Co-operation of the Workers.

To enlist the co-operation of the glass blower, or the worker in glass, is the first step in any scheme devised for intensifying production. Customs are hard to break down, but they give way in response to appeals made to intelligence. Propaganda, incessant rumour talk of what is about to be done, and why, and foremen's meetings, all maintain enthusiasm and foster the progressive spirit. Informal talks with the men's committee, with a blackboard for illustrating points and explaining figures, rarely fail to convince them that foreign competitors' methods and prices are a challenge. But if there are rewards at the end of the production programme,

the men must share; particularly if one programme is going to be followed by another and still another.

An efficiency monitor which works well in the U.S.A. is that of setting up temporary ideal standards of efficiency. When these are reached others are set up with the lure of the attainable. The lure rests in the standards having been shown to be possible.

Conclusion.

The principles underlying the organisation at Lemington Glass Works are fundamental, and as such are applicable to the manufacture of any kind of glass from pot furnaces. They are directed to the elimination of waste. To reiterate, if the furnace be regarded as plant for melting a maximum quantity of glass, the desire and effort to make it do so will direct the necessary ways and means in individual circumstances.

I have to thank the Directors of the General Electric Co. for their permission to use the information contained in this paper.

LEMINGTON GLASS WORKS, LTD.,
    LEMINGTON-ON-TYNE.

DISCUSSION AT THE NEWCASTLE MEETING.

The PRESIDENT, opening the discussion on the paper, said: Speaking for himself, and he really did think he could speak for all present, this was one of the most interesting papers that had been read before the Society. The subject made its appeal to all members, and could be understood even by the wayfaring man. What stood out in this paper was the idea of the elimination of waste. The paper demonstrated most effectively that what were needed in the works were, above all else, enterprise and a continual willingness to re-direct and re-shape one's efforts to seek ever a higher standard of attainment. For such an achievement, the mind had always to be plastic and the relationship between all classes of the workers had to be controlled rather by a disposition to seek an ideal than by cast-iron rules of operation; in other words, success could only be fostered by a good spirit between all parties. The paper was one which should produce questions and discussion for a considerable time. He would suggest that this paper be circulated, and a re-discussion of it be organised at some future meeting. Turning to details, he did not know quite which point to take first. There were one or two passages concerning the technology of glass to which he might refer. The first was the suggestion that harder glass—for example, soda–lime glass—might

be melted successfully in the open pots. He might mention that hard combustion glass was made on the Continent in open pots. Again, Mr. Warren had not specifically dealt with sizes of pots in relation to the time of founding and the nature of the batch, although no doubt he could express an opinion on these subjects. On the Continent, for chemical glass and other hard glass, the size of the pots was comparatively small, often being from about 250 lb. to 500 lb. in capacity, in order to permit of rapid melting.

In regard to the subject of the grouping of the glass-workers, most of those present would have been astonished by the fact that fourteen men would be needed per pot to work out all the metal in eight hours when making bulbs weighing 4 lb. per 100 bulbs. He had seen eight men per pot on the Continent, and the sight was very impressive. Concentration of labour was likewise adopted in making small bottles in America. He (Prof. Turner) had seen as many as twelve chairs, seven to a chair, or eighty-four workers round the nose of a comparatively small tank furnace. To get such conditions required intelligence in working out, and Mr. Warren and his colleagues at Lemington had set a standard which must not only draw admiration from other manufacturers, but also furnish the latter with ideas for application to their own particular types of manufacture.

MR. F. GRAVES CLARK said he thought Mr. Warren and the Lemington Glass Works that day had given them decidedly new ideas of glass-making so far as pot shops were concerned. He was particularly struck by the ideas of ladling from pots into working tanks, and of keeping the pots on the go all the time. Where he came from, the pots were often left standing full of metal, perhaps for a day, waiting to be used up, whereas if the pots could be ladled as soon as the glass was melted there was no doubt a much bigger production could be got from the furnace. In regard to the pots themselves, the idea about the back of the pot being thicker than the front part was very important. At his works, exactly the same idea had been adopted only a few months previously, and although the pots had not come into use yet, he thought they would get better results. In regard to a D-shaped furnace, he was not quite sure what Mr. Warren meant.

MR. T. TEISEN : In regard to the life of the pots, he considered the time of three or four months allowed for the pot tank combination rather high as compared with the six weeks for the ordinary pot furnace. It should be borne in mind that the pot in the first case would be melting all the time and consequently at a melting temperature and corrosion such as honeycombing would take place at a greater rate in that pot than in the other case, where it was

only kept at a melting heat during the night. As regards the statement that a recuperative furnace responded more slowly to adjustment in temperature, he was rather inclined to think Mr. Warren had based his statement on the furnaces in his works. In this case he actually compared the smaller 5-pot **D**-shaped regenerative furnaces with the large 10-pot recuperative furnace. It was a well-known fact that smaller furnaces responded more quickly than bigger ones and that was the main reason he believed in this case. Besides, the regenerative furnace had no doubt in this case a higher margin of producer capacity than the recuperative, in which it might be on the low side. He referred to the Dutch works mentioned elsewhere in which furnaces of equal size, recuperative and regenerative, respectively, were employed and in which the recuperative furnace more quickly rose in temperature. (This was also clearly seen from the temperature charts of the recuperative and regenerative furnaces at the above-mentioned works, a reproduction of which was given on page 13 of the March number of the Journal, whilst the corresponding curve for the larger Lemington furnace was given on page 11.)

That Mr. Warren had been able to run the 10-pot recuperative furnace with pots of 38 inches diameter on the melting by night system was an achievement and one on which he should be complimented. At the same time, he (Mr. Teisen) was still of the opinion that a furnace of somewhat smaller capacity would be more in its place for that purpose.

The paper was, he thought, one of the most interesting he had ever listened to, rich in information which would be of value to everybody connected with the glass trade, and he was looking forward to reading the paper later on with the view of going into further questions which might occur to him.

MR. G. BARRAS thought the methods laid down by Mr. Warren would certainly be applicable to a very large proportion of the glassware made. As a glass-maker and one who had seen the transition from the old methods to the new, he knew something of what might be done in increasing the production of such articles as table-ware as well as bulbs. It was all a question, as Mr. Warren had said, of organisation. They had realised that to the full at Lemington, and the same ideas could be made to apply to the general run of table-ware manufacture. In the case of glass tubing, the practice had been for only two men to be working from a pot, but they had been struck with the idea that it was a mistake altogether to need eight hours to work it out. They wanted to reduce that period, and, for that reason, had a glory hole erected, so that, instead of working two men only, six men could be accom-

modated, with the result that the pot was emptied and four hours on its found before the men normally left. If there were well-arranged glory holes, instead of only one chair gathering from a pot, it was possible to have four chairs. What applied to that particular kind of ware could apply to others. If they were to keep abreast of the times it was very important that a pot should be occupied in melting glass and nothing else. He thought there was the possibility of great improvement in the table-ware trade, which was up against keen competition, but if scientific methods and organisation were applied, there were great possibilities of improvement, and foreign competition could be met.

MR. T. W. FERRY, referring to the comparison made by Mr. Warren between the round and the rectangular furnaces, said that with the small rectangular furnace used at the Tyne Glass Works they could not work twelve men at the small 2-pot furnace. If the furnace had been circular, they could easily have done so. He was sorry there had not been more manufacturers from the Midlands present to hear the paper, and considered that the suggestion to have it circulated was a very good one.

MR. W. BUTTERWORTH asked if Mr. Warren thought more could be done by local cooling of the pots with air. In that case one could have larger pots, and work at one pot twenty-four hours, employing three shifts. It seemed to him that a very large output could be got that way from a big 12-pot furnace with large 30-cwt. pots.

PROF. W. E. S. TURNER said he was particularly struck with the diagram in regard to the variation of the load in electric generating stations and the move that was made to sell power cheaply. It was on a similar basis that some German firms before the war, making not only glass but many other things, were able to export their goods cheaply. The importance of reducing overhead charges was not sufficiently realised. He would also like to refer to Mr. Warren's suggestion to rotate the pot in the furnace and so maintain a uniform temperature. However revolutionary the idea, the engineer does not stick at anything. In this connection he would like to add that a patent was granted in the United States in 1921 to Scholes, Nicols, and Kaufmann for a method of tilting and rotating a pot inside a furnace with the view of removing striæ. He was glad the idea of having this paper set up and circulated for further discussion met with approval.

MR. WARREN said he would be only too pleased to be at any meeting for the further discussion of the paper. He rather wished to provoke a discussion. He was reminded by Prof. Turner that he had not mentioned the size of their pots. They were 38 inches

by 40 inches by 40 inches. He was not altogether unaware that hard glasses were melted nightly in small pots, but thought that by using rotating pots one could melt much larger quantities.

In reply to Mr. Clark, the D-shaped furnace was the semi-circular furnace.

Mr. Teisen questioned the life of the large pots proposed for the pot-tank furnace and considered the estimate too liberal. A life of three to four months was in accord with experience under similar conditions. The recuperative furnace with open pots was somewhat more difficult to control during the working period than the regenerative furnace. Unless the damper was sufficiently open and drawing in excess of cold air, which unduly cooled the recuperators, the glass blowers had their hands burnt. Conse-quently, on charging the pots for the founding the cold recuperators retarded somewhat the necessary increase of temperature.

Mr. Barras considered that the manufacture of table-ware could be organised on somewhat similar lines to those which had been applied to bulb making. Mr. Barras had had a wide experience of both those businesses, and in consequence could speak with authority. He (Mr. Warren) also believed it possible. In his view, it was only a question of breaking down inherited traditions.

With regard to Mr. Butterworth's suggestion that pots of metal might be cooled with air : they frequently had done that when founding and melting simultaneously in a furnace, and had derived a distinct advantage in doing so ; but that was in the days of the coal-fired furnace.

Mr. Butterworth : If one reckoned 4 lb. to 100 bulbs, 450 lb. represented over 10,000 bulbs. If a man made 1,000 a day, which was a high figure, only about ten men would continuously be required to produce 450 lb. weight of saleable ware. He gathered that only six men could work at one pot. In such case was there not a quantity of metal left ?

Mr. Warren : It was possible to have a double working hole and work twelve men at one pot ; by so doing one obtained 12,000 bulbs.

Mr. Butterworth : Not for every furnace ?

Mr. Warren : No ; there were 8-pot furnaces which were given up to small bulb work, with 12 men at each pot.

Discussion at the Sheffield Meeting.

Mr. W. Butterworth : Mr. Warren had certainly brought his production to a high state of efficiency. He worked his pot out six times per week, as against the American average of three times. This doubling of the output per pot-capacity no doubt made his system definitely superior.

His method had, however, certain drawbacks. Drastic demands were made on the furnace. A founding temperature of 1,500° with covered pots, and the rapid change back to 1,100°, caused the pots to be short-lived, and the furnaces more so. The temperature of the furnace was not a uniform 1,500°—it would be considerably higher at the secondary air inlets. His (Mr. Butterworth's) own firm had had great difficulty in getting refractories which would stand up to a decidedly lower temperature. The requirements of modern high-temperature furnaces seemed at the moment to have definitely outrun the capacity of makers of refractories. It was to be hoped that refractories manufacturers would be stimulated to get ahead again, like safe-builders against burglars. A furnace with large pots, on the other hand, which were worked out on alternate days, could be kept at a steady and moderately high temperature throughout the week, the pots being cooled locally for working out. The cost of fuel in the large furnace was relatively less per pot-capacity, and the depreciation very much smaller. There was no reason why the large furnace should not have a life of five years, as in Mr. Warren's pot-tank combination; whereas he estimated, quite liberally, the life of his small furnaces at two years.

When all was said, however, the Lemington practice seemed much superior to the American. But turning to other types of work, day-work often became less desirable. One was entirely restricted to soft glasses in this system. Further, in articles requiring annealing one must double the lehr capacity if work is confined to the daytime. This greatly increased the fuel and upkeep expenses, and it might be difficult to find the extra lehr-room in an old factory. In heavier work than bulbs, either pressed or blown, which required annealing—and this included most types of glassware—he should regard it as preferable to have a furnace with large pots and to aim at working each out four times weekly, rather than have small pots worked six times weekly. In the former method, there would be a day and a night shift with one-third of the furnace worked out each shift, so that each pot would be worked out once every thirty-six hours. Seeing that the larger the pot the longer it took to found and to work out, the furnace should be designed to take pots of such a size that the metal to be used could just be founded and worked out in this period. It could then be arranged that there should be just enough men on a shift to work out their quota of pots in the duration of the shift. For instance, in a 12-pot furnace 4 pots per shift would be worked out. One would probably work them in pairs, emptying each pot in four hours. In a thirty-six hour cycle, of which only four hours were spent in working out, it should be possible

to use very large pots with a soft metal, and fairly large ones with a harder metal.

Allowing two hours for preliminary local cooling, the glass would thus be founded for thirty out of each thirty-six hours. In Mr. Warren's pot-tank combination, allowing two hours for ladling, thirty-four hours would be the founding time. Thus, regarded as a melting machine, his furnace would have an extra efficiency of about 14 per cent. A rough-and-ready test of the desirability of the pot-tank combination would be afforded by calculating whether the introduction of the tank added more or less than 14 per cent. to the fuel and other running costs of the melting furnace.

To found four times per week in large pots was of course well on the way to perfection. Many manufacturers were engaged in miscellaneous work, in which the weight of metal worked out varied greatly. More than one kind of metal might have to be melted in the furnace, and for this reason it was desirable to keep one set of workmen always engaged in the same pots. This made it impossible to work out the pots more than three times weekly. They were, in fact, engaged in a continual improvisation, which showed up very badly beside Mr. Warren's ordered system and imposing efficiency.

Mr. Guy Simpson said that Mr. Warren had spoken of the furnace temperature as 1,600°. They reached that temperature sometimes in a steel furnace, but in a pot furnace it tended to be lower.

Mr. F. F. S. Bryson thought that the idea of the rotation of the pot was quite good so far as the life of the pot was concerned. There was, however, a question of the engineering difficulties. It would be rather a big engineering problem to keep going a plant suitable for rotating the pot.

With regard to the corrugated pot Mr. Warren had suggested, he did not know that that was going to get over the trouble of cracking the inside of the pot, because there would be a certain amount of penetration by the glass. If the corrugated pot was used in the way that the small pots had been used before, namely, under very variable conditions, even then one would get the cracking due to the expansion of the pot on cooling. Nevertheless, he thought both suggestions were very valuable.

Mr. J. R. Clarke thought there might be some additional pressure on the sides due to rotation. He did not know whether that would shorten the life of the pot, but if so the pot would have to be strengthened.

Mr. Donald Robertson said in Glasgow there were two furnaces

of eight pots, each holding 15 cwt., for pressed glassware. They used to get roughly three founds per week, melting usually taking place on Sunday night, Tuesday night, and Thursday night. It was noticeable that when the wages were made up to Thursday night, Thursday's production was always very much greater than any other day in the week. That was quite a common thing.

Mr. Warren had mentioned the fact that he did not understand why manufacturers in this country should be content with direct-fired furnaces. Very often the question of finance came in. It often meant that a small private manufacturer had got to form a company to raise money.

MR. R. HEMINGWAY asked in regard to Mr. Warren's pot-tank combination if he meant that the dividing wall was built up to the crown so that the tank was only heated by means of radiation through the dividing wall. As this was most improbable, then the metal in the tank would be under the influence of the furnace gases to a certain extent. Why, therefore, not melt the glass in a tank furnace and thus save both time and money ?

MR. F. G. CLARK asked if it were possible to keep the temperature of the tank fixed all through from week end to week end. He thought one of the main reasons why English manufacturers had gone in for direct-fired furnaces was because they had been most unfortunate with regard to the pots with gas-fired furnaces. Gas-fired furnaces led to a bigger percentage of cracked pots.

He said he would like to mention one other point, and that was with regard to pots cracking at the back. He had noticed several times that when there had been a crizzle across the crown, the pot had not cracked at the back nearly so much as when the pot had been perfectly sound on the crown. Perhaps some man of science could explain that.

MR. F. W. HODKIN (*communicated*) said Mr. Warren, in addition to presenting them with many interesting facts, had made a number of suggestions which provoked certain discussion. His pot-tank combination, particularly in view of his statement that "for most purposes the circular gas furnace is to be preferred," appeared to be a somewhat cumbersome outfit. If a tank was to be used at all, why employ pots ? The pots in the rectangular portion of the combination were scarcely likely to be of equal efficiency for melting, since it would be probable that the pots in the four corners would be cooler than the others.

The suggestions regarding pot construction were distinctly revolutionary. Pots with thick backs had been tried in several works, but only, as Mr. Warren had stated, with a fair measure of success. The internal ribbing of the pot might be a feature giving

additional mechanical strength, but the surface exposed to corro-
sion by the glass would be increased. A similar objection might
be made to a pot with re-entrant angles, and, in addition, the
inner angles would tend to be cooler than the outer ones.

Ladling was liable to be prejudicial towards pot life. Could
Mr. Warren say whether his pots when removed from the furnace
showed signs of pieces having been removed from the internal
walls due to suction caused by ladling ?

The furnace temperatures given by Mr. Warren were rather
startling, and he suggested in a possible revolving pot furnace a
temperature exceeding 1,500°. In replying to Mr. Guy Simpson
at the April meeting, he (Mr. Warren) mentioned a special refractory
used at Lemington capable of easily withstanding this temperature.
Could Mr. Warren give them any further information regarding
this refractory material and also as to the clay he would use for
pots in such a furnace ?

MR. G. S. DUNCAN (*communicated*) referred to the table in which
Mr. Warren endeavoured to form a comparison between the pot-
tank furnace combination and the simple pot furnace. Would it
be possible to state the approximate relative cost of production
per unit in each case ? At Lemington the pot-tank combination
was used in conjunction with the automatic Westlake machine,
whilst hand labour was employed at the pot furnaces. In arriving
at such costs, was interest on capital included ? There would
appear to be some ground for its inclusion, seeing that in the one
case expensive machinery was utilised, in the other case com-
paratively little. It would be interesting to have Mr. Warren's
views on a subject on which even cost accountants were not agreed.
Presumably, automatic machine-working was the more efficient
and would ultimately entirely displace hand-working.

MR. WARREN, in reply, said, considered solely from the point of
view of cost of pots and repairs to furnaces, Mr. Butterworth's
strictures on high temperature founding were sound ; but he was
sure he (Mr. Butterworth) would be the last to overlook the effect
on total costs of quick turn-over. Confusion of thought was
introduced by measuring the life of a pot or furnace by speaking
of it in reference to a period of time. To be accurate, the life of
a pot, for instance, should be calculated in terms of the number
of founds, or of the total weight of the glass melted.

He was not sure whether they were on common ground when
Mr. Butterworth spoke of the life of a furnace. The period or
interval between small repairs, which at Lemington they were
able usually to complete in a week, was not the same as the interval
of time between entire rebuildings of a furnace. The small furnaces

at Lemington had been constantly in operation for seven years, except for occasional repairs to the seats and pillars, and less frequently to the crowns.

There were undoubtedly, as Mr. Butterworth reminded them, individual cases, such as in the manufacture of pressed glass, in which it would be inadvisable to adopt a day-work system, but he contended that those operations should, and could, be less interrupted by shortage of metal if a bolder policy in the melting conditions were adopted.

Mr. Butterworth postulated an extreme case of a large furnace and large pots, and compared this with the suggestion of a pot-tank furnace. The extra melting efficiency of the pot-tank furnace would be 25 per cent., not 14 per cent. as he calculated. That increased efficiency would be obtained by melting and ladling during the week end, which was one of the peculiar advantages of the combination. A further advantage was, and Mr. Butterworth emphasised this by mentioning miscellaneous work, the number of working holes which might be introduced into the working tanks in excess of the number of pots, thus affording better facilities for a variety of work and a larger number of men and machines. Moreover, the furnace would provide for two kinds of metal, one in each tank.

He was able to say, unhesitatingly, with actual figures before him of the cost of operating a 12-pot furnace with large pots, that an 8-pot furnace combined with tanks would not only melt a larger quantity of metal, but the total costs of that larger output would be less.

Mr. Guy Simpson was surprised at a temperature of 1,600° being mentioned. It was the case, however, that at Lemington they frequently exceeded 1,500°, using " run of mine " coal in the producers. As the result of the experience of high temperature founding it was his opinion that 1,600° could comfortably be attained in small furnaces with gas having a calorific value of 160 B.T.U. The crown of the furnace should be constructed of aluminous material, lagged with insulating bricks, and the tie rods carefully adjusted as the crown bricks contracted. He was not bold enough, however, at this stage of their experience of refractories to suggest that the crowns of large furnaces should similarly be constructed.

The insulating bricks loosely placed on the crown of a pot furnace were on one occasion quickly removed, with a resultant immediate drop of temperature in the furnace of 60°.

At first sight, Mr. Bryson's apprehension regarding the difficulties of rotating a pot might be understood. Not all furnaces were

adaptable to the simplest way of approaching the problem; but, given a furnace design which lent itself to a method which circumvented the major difficulties, the idea looked easily workable. The power required to rotate a pot slowly, after starting it in motion, should not exceed one h.p.

The suggestion of making pots corrugated occurred as the result of having observed, as Mr. F. Graves Clark had also observed, that pots with vertical ruptures in the front, and that had been concaved, had an unusually long life. For the purpose of inquiring more thoroughly into this, a new pot was cut with a saw from the top to the bottom, placed in a furnace and concaved in the usual way. On carefully watching the saw cut it was noticed that the width of the cut varied considerably as the temperature varied. Pots, therefore, had a certain amount of elasticity. The life of a pot for high temperature conditions depended, not so much on its ability to withstand corrosion, as to stand up to high temperature and variations of temperature. A corrugated pot was more flexible and had a larger heating surface than a plain pot.

He thought he could assure Mr. J. R. Clarke that the torsional stress transmitted through the bottom and wall of a pot when it was rotating one revolution in, say, two or three minutes was negligible; so also were the centrifugal forces.

As Mr. Robertson remarked, it was a fact that men, being human, were influenced in their efforts by the uplifting thought, " pay day is to-morrow." This was an argument in favour of paying bonuses weekly instead of monthly, or at longer intervals.

When he mentioned that he was unable to understand why glass manufacturers in this country should be content with direct-fired furnaces, he was thinking more particularly of those who were financially strong enough to make the change.

In reply to Mr. Hemingway's questions, the tanks would be heated by radiation, there being dividing or shadow walls between them and the pot furnace. When a lead glass could be successfully melted in a tank, and when the colour and quality of any other kind of glass were consistently as good when melted in tanks as they were when melted in pots, Mr. Hemingway's second question would have point. The question, however, indicated a progressive spirit.

Possibly Mr. Hemingway was of the opinion that the advantages of melting in a pot, as regards quality, were thrown away when the glass was ladled into a tank. His own experience was that that was not the case. When tanks at Lemington, into which glass had been ladled, had been shut down, the glass, even on the bottom of the tanks, had been perfect in colour and free from defects. Both lead oxide- and soda–lime glasses had been tested in this way. The

tanks, it must be remembered, were maintained at a temperature not higher than 1,200°, and were not subjected to the corrosive action of raw batch materials.

Mr. F. Graves Clark asked for information regarding the temperature of the working tanks. The temperature of the surface glass in each tank would vary 50° as reversals took place in the pot furnace, but as the boots would be placed some depth in the glass reservoir, which was also a reservoir of heat, the temperature variation would be slight. Otherwise, both the temperatures of the pot furnace and of the working tanks would be reasonably constant, provided the producer plant was designed to take care of gas conditions while producers were being cleaned.

He must agree with Mr. F. Graves Clark that manufacturers in this country had had unfortunate experiences with pots in gas-fired furnaces. At Lemington, despite the temperatures to which they subjected their pots, they had not been quite so unfortunate. He believed this to be partly due to the fact that the staff at Lemington had acquired the knack of handling gas furnaces, and partly to their having avoided weak points in their design and construction. Pots were, however, their greatest trouble and to their improvement they had a given a deal of time.

Mr. Hodkin isolated a phrase and accused him of inconsistency. His statement was, " For most purposes circular gas furnaces are to be preferred. They provide around the pots working spaces which furnish better facilities for a large number of men than rectangular furnaces do." In the pot-tank combination the working tanks had circular boundaries into which the working holes were arranged. The pot portion was rectangular to facilitate the joining up to it of the working tanks and to provide a straight path for ladling with the assistance of a run-way. Until tanks became universal for all kinds of glass, a pot-tank unit, which was intermediate in its melting efficiency between a tank and a pot furnace, would for a wide variety of purposes, despite being ungainly in appearance, show quite a considerable saving over pot furnaces having a similar production capacity; and when one considered the loss incurred by tanks having to be put out of commission every year, and in some cases every six months, the question arose whether steady production for five years from a pot-tank at the cost of a slightly lower efficiency, plus the difference between the cost of the pots and the cost of the tank-block, would not strike a balance between the two types of furnaces.

Mr. Hodkin's objection on the score of corrosion to pots other than those with a plain wall was, in the case of high temperature work, of secondary importance. He (Mr. Warren) excluded glass

of optical quality. To guard against the sudden rupture of the wall was the pressing problem. Ladling had no prejudicial effect on pots.

At Lemington a highly aluminous material was used practically everywhere in the furnace where temperatures were extreme. Such material was both very refractory and resistant to glass attack. A mixture of clays with nearly 50 per cent. grog was used for pots.

In answer to Mr. Duncan's question as to the relative costs of production per unit for the pot-furnace combination and the simple pot furnaces, the figures were 86 and 100. In arriving at the costs as between the Westlake machine plant and the plant entirely operated by hand labour, interest on capital was not included, but a composite figure for depreciation calculated on the estimated life of the various portions of the plant and buildings was included. The item of cost charged for depreciation would necessarily be heavy for expensive machinery, particularly if obsolescence were taken into account. To the " all-in " manufacturing costs was added a percentage as profit, or interest on capital and provision for reserve fund, etc., if the market or competitors' prices would permit of so doing. In the case of public utilities under the management of municipal authorities, who did not seek to make a profit, but probably had hopes in that direction for the relief of rates, interest on capital was included in costs as well as depreciation.

Until standardisation of bulbs was complete, there would always be room for a certain amount of hand labour for small lines of special types. The cost of moulds for a Westlake machine was considerable. This and similar exceptional costs had to be taken into account when deciding the uses to which automatic machinery might be put.

IX.—*Tank Furnace Works Organisation.*

By T. C. MOORSHEAD.

(*Read at the Sheffield Meeting, April 18th, 1923.*)

I UNDERSTAND that the subject to which this paper is a contribution is that of Tank Furnace Works Organisation, and the discussion is, I believe, a sequel to the paper read by Mr. W. W. Warren on " Organisation for Production from Pot Furnaces."

I am not, however, going to confine myself in these remarks to

the works organisation of a tank furnace, because it rather seems to me such a simple thing that there is nothing really to say, particularly after the very instructive and interesting paper of Mr. Warren on pot furnace works organisation ; for, after all, there is very little difference between the organisation for production from a pot furnace and the organisation for production from a tank furnace—at least, not enough difference, it seems to me, to say much about it.

I am, however, going to treat the subject rather more broadly, that is, rather as " Works Organisation " ; and although the fundamental principles are the same for all works organisations, we will, in dealing with the general subject, consider their application to a bottle manufacturing plant. I hope that these few generalities which I am going to get out of my system will serve some useful purpose, and, at least, give us a basis for detailed discussion.

I am not going to say anything about plant design or equipment, but in discussing general works organisation I am going to assume that both plant and equipment are modern and up-to-date ; for the question of plant design, lay-out, and the character of equipment in it is strictly a technical subject and one which has really nothing to do with works organisation, particularly as regards the production.

A good capable manager could, with a proper organisation, take an old obsolete plant and get a good production or very much higher over-all efficiency than a poor manager with a poor organisation could with a modern and up-to-date plant ; and, if this is true, as I think will be conceded, the subject of works organisation is highly important, and, in fact, just as important as the technical details of a plant.

It has been said by many industrial engineers and efficiency experts that the over-all efficiency of the average manufacturing institutions is not more than 50 per cent. By over-all, we mean from the manager down to the lowest subordinate in the plant, and from an experience of something more than twenty years that I have had in bottle manufacturing plants, both in the technical departments and in the management, and with every process from a pot furnace to the latest type of automatic machine, I am quite ready to believe that this statement is a very close approximation, and particularly so in the average bottle manufacturing plant. Certainly, if this is true, it gives us a very great margin for improvement and only further demonstrates the fact that the works organisation is a very important subject.

Assuming that in a well-designed plant, equipped with most modern machinery, the general over-all efficiency is only 50 per cent.,

obviously, works organisation, or we may probably better say lack of organisation, is responsible.

Of course, every factory manager, managing director, factory owner, or whoever may be responsible for the organisation of the particular factory, although he may not claim that the over-all efficiency of his plant is 100 per cent., or, in other words, that he has a 100 per cent. perfect organisation (he would be a cheery optimist if he claimed it was), and even might agree that his general over-all efficiency was only 50 per cent., he probably would not agree that he had no organisation; for most men think that the employees who go to make up a plant is an organisation.   But a great many of them are not organisations, they are simply conglomerations of men thrown together and acting, or working, without full knowledge of their responsibility or any impression of the necessity of co-operation.

What is an organisation ?

As applied to a manufacturing industry, it is a combination of men arranged or distributed in parts or groups with proper officials, managers and foremen, and so co-ordinated that they are able, with the aid of such machines and tools as they may have available, to produce a finished article efficiently.

If this is accepted as a definition of an organisation, let us try to determine where, although the organisation may substantially comply with the definition, great losses in efficiency may occur.

Most organisations will, I believe, comply with the definition we are giving, in this sense, that they are made up of a combination of men arranged in groups with a foreman, superintendent, or manager in charge of each group, and the whole combination in the charge of one head official.   But does it operate efficiently as a whole, or, in other words, are the various groups properly and thoroughly co-ordinated ?   Do the separate groups each operate up to the highest standard of efficiency ?

Some of the groups in the organisation may do so.   Several may not.   Each of the individual groups may be very efficient, but still they all must be properly co-ordinated, so that there is a close co-operation between all of them.

It is therefore obvious that to get the best results, each group must be under an efficient and capable head—we will call him foreman—who must not only have initiative, but also be capable and willing to carry out instructions coming from higher up; and he should have a thorough knowledge of the work that he has to do, or is responsible for, and, therefore, be able to carry it out in the most efficient manner.   And, in addition to this, each of the groups in the whole combination must be made to co-operate one with the other, particularly where their work by necessity overlaps, so that

the whole of the organisation is thoroughly and properly co-ordinated.

If it cannot be said assuredly that each one of the groups is composed of capable men, each group in charge of a capable foreman, the foremen all capable and co-operating under a capable superintendent or shift manager or head, whatever he may be called, who then is responsible ?

If you have some men inefficient, indifferent, and disloyal in a certain group or department, who is responsible for these men ? One would naturally say the foreman ; but then, we may ask, Who is responsible for the foreman ? Certainly, if he is trying to carry on his work with inefficient and incapable men, then he is not a capable man, and who is responsible for him ? The man who is next above him, we will say, the shift superintendent ; therefore, if there is an incapable and inefficient foreman in charge of a group, the shift superintendent is responsible, and if he is responsible and he permits this condition to exist, then he is inefficient and incapable, and so we carry this along the line to the active head of the institution, and there we find the really responsible man for the losses in plant efficiency. He is the man who is really responsible for the colossal waste that is going on every day.

I have heard some of these same industrial engineers and efficiency experts who have stated that the average manufacturing plant is only 50 per cent. efficient, also say that 80 per cent. of this tremendous loss of efficiency was due to the manager, or, in other words, due to a lack of proper or efficient management ; and I am prepared to accept this statement as true.

Of course the statement has been accepted that we can never be perfect, nothing will ever be perfect ; but here I might tell you a short story : A schoolmaster once said to one of his scholars, " Johnnie, what is the sum of nine and six ? " Johnnie quickly answered, " Fifteen, sir." The master said, " Very good." Johnnie said, " Very good !—Hell—it's perfect ! "

Although in this case Johnnie displayed 100 per cent. efficiency, I agree that we probably cannot continuously reach 100 per cent. efficiency. If I said we could, I would condemn myself, and as self-preservation is one of the first laws of nature, I am not going to say that we can ever have a perfect organisation, but, as I said before, accepting the statement that the average plant is only 50 per cent. efficient, we, I think, will all admit that there is plenty of room for improvement.

I should say that, in a bottle manufacturing plant, the causes for these losses of efficiency could be grouped under five headings as follows :—

1. Faulty raw material.

2. Poor labour, that is, incapable, indifferent and disloyal employees.

3. Poor attendance.

4. Large labour turnover, or ratio of men leaving to the number of men on the pay-roll.

5. Machine or mechanical breakdowns.

There are, of course, thousands of little things, many of which occur every day, that cause grief and trouble to the glass factory manager, but I think that all of them can be, as I stated, grouped under these five headings, and these difficulties, troubles, or failures, I am quite sure, we shall find can all be traced back to inefficiency on the part of the management, and probably to three things :—

1. Lack of foresight.

2. Lack of thorough knowledge of the factory operations.

3. Lack of initiative.

Let us now take these various headings and see where organisation affects them :—

1. *Faulty Raw Materials.*

I think every glass manufacturer fully appreciates the importance of pure raw materials. You have all, no doubt, on many occasions suffered great losses in production on account of bad glass which could be traceable to faulty or impure ingredients, and it is therefore necessary to—and surely the manager with foresight will—provide for every contingency possible to insure himself against this trouble, and the obvious way to do this is to have a department in the organisation for dealing with it ; that is, that it should be one man's responsibility. This may be either the buyer or preferably a works chemist, to investigate the sources of supply, to make provision for constant and regular supplies, to keep a sufficient quantity in store at all times in order to ensure the factory against shut-downs in case of failure of deliveries, to analyse frequently the materials for purity, and to see that they come up to specification.

In some organisations, and the one I am connected with happens to be one, it is necessary to divide this responsibility, and in our case it is done between the buyer and the head of our research department, who, however, work in close co-operation under the general management.

The sources of supply for the various raw materials, particularly of sand and lime, are constantly being investigated with the view of getting better quality and cheaper costs. Specifications are made

up by the research department for all the raw materials, for the information of the buying department. The buying department is, of course, responsible for the purchase of the raw materials and also for their transport, which is looked after by the transport department under the jurisdiction of the buying department.

In addition to analysing samples of the raw materials as they arrive at the plant, with the view of reducing to a minimum the possibilities of impure materials getting into the batch, means are provided for carefully watching the handling of the materials in order to reduce to a minimum the possibility of contamination ; and, in addition to this, regular analysis of the glass is continually made in order that its characteristics can be closely watched and such changes made as may be necessary to keep these characteristics constant.

At the Charlton plant, where we have a mechanical plant for the handling, mixing, and distribution of the batch, no change of any kind whatsoever is permitted to be made in the proportioning of the materials without the approval of the research department. Even with the comparatively complete organisation that we have for watching our raw materials from the source of supply up to the time they go into the furnace as batch, we still have our troubles.

Changes occur which we cannot account for, which only proves that although we have what we think is an efficient organisation for that particular phase of the operations, there is probably something wrong with it, and improvements can probably be made. Obviously the management is responsible for these deficiencies ; for it is, of course, up to the manager to study continually his organisation and try to locate the weaknesses and make such changes as may be necessary to strengthen it, and unless the manager makes constant and conscientious efforts to do so, he, of course, is not up to his job.

2. *Poor Labour.*

This problem is, of course, a difficult one, and to some managers is probably one of the greatest sources of trouble.

In the author's opinion, there is only one way in which to deal with this problem, and that is, at the source. By this I mean having provision for carefully investigating every application for work in the plant, and, in addition to this, having the applicant interviewed by a man who is a good judge of human nature.

After the man is employed, there should be means of carefully watching his progress, and where it is evident that the man is not interested in his work, or is an agitator, he should, of course, be immediately discharged.

These, of course, are common-sense rules that probably every

factory manager or owner realises, but, from my experience, they are not fully appreciated, at least to the extent of making special provision to analyse the character of the applicant as carefully as they would analyse raw materials that go into the batch.

There are, it need scarcely be said, many ways of doing this, and there are probably many better ways of doing it than we have employed in our institution ; but to give an idea of one way in which this can be done, I may say that at the Charlton plant of the United Glass Bottle Manufacturers where I was responsible for building up a works organisation, and where it had to be done with practically all inexperienced labour, and where also we had little knowledge of the local conditions, we made out a special form of application, and one man was employed particularly for the job of receiving and interviewing the applicants, and afterwards investigating their records before they were employed.

This application form included many questions which, to most of the applicants, seemed to be non-essential, and probably to many plant managers it would also seem immaterial; but the questions were set for the purpose of ascertaining how intelligently the applicant would answer them ; what his attitude was in answering them—for some of them were very much of a personal nature—and how truthfully he answered them, which we determined by investigation afterwards.

By this means our employment man was able to judge very closely the general characteristics of the man. He knew from his general attitude and mannerisms in answering the various questions whether he was an agitator, whether he was ambitious, or whether he was simply a drifter who floated from one place to another wherever it might suit his convenience, or, we may say, one who followed the line of least resistance ; and when it is considered that we have an open shop at the Charlton plant and have had a comparatively small labour turnover and no labour troubles worth mentioning, I think we can safely assume that at least we have accomplished something in the way of obtaining a good quality of labour.

3. Poor Attendance.

This, of course, like the preceding problem, has to deal with the human element and is likewise a difficult one.

You may fill up your plant with capable men, reasonably ambitious men, and men who do not shirk while they are on the job, but you may be troubled with poor attendance ; that is to say, where a man is supposed to work five and a half days a week, or six days, whatever it may be, he only averages four, under which condition efficiency drops off because, when the regular man is not on his job, there

must be someone to take his place who is not conversant with all of the little kinks like the regular man, and mistakes are liable to occur that eventually bring about loss of production.

In my opinion there is a fundamental principle on which we may be guided in dealing with this problem, and that is, make a man's work interesting.

This may be done first of all by being sure that the men understand *what* they are doing and *why*. If the department makes only a part of the complete product, let them know about this part, what it does, why it must be made well, and what the output must be to keep the production of the whole plant up to where it belongs. Keep the idea of quality always uppermost. Show them the advertisements and point out that it is the job of the shop to try to make every claim come true to the consumer.

Be sure that each man knows just what his part plays in the complete unit. Show how slighted work will affect the whole product—how this hurts the reputation of the firm and means loss of orders and the laying-off of men, thus harming all concerned.

The more the men know about the *material* they work with the better. It is another point which can be emphasised to increase interest.

These are simply ideas that suggest themselves to me and which, I may say, we attempt to carry out in our own plant, by means of getting the men together occasionally and talking to them; but particularly by means of weekly managers' and foremen's meetings, at which time the entire plant staff, that is, the managers, shift superintendents, and foremen, get together at a convenient time for conference and discussion on an agenda made up from suggestions that have come from various men and foremen through the week.

A full and complete record, or minutes, of these meetings is kept and copies are circulated to each of those who were present, and one copy is sent to the head office, this copy coming to me. From this I can keep in very close touch with the troubles that are cropping up daily (and I may say that troubles are the only things I am really interested in, because it is by the elimination of troubles that we gradually increase the plant efficiency) and I can make any comments that I desire, sending these comments back to the plant manager, so that they may be circulated among the foremen and sometimes come up for further discussion at the following meeting. By this means it is possible for the management also to deliver messages of advice and to issue general instructions regarding various phases of the operations.

4. *Large Labour Turnover.*

This trouble also, of course, deals with the human element and may be said to be very closely allied to the second trouble, namely, poor labour; but it is different from both of the preceding problems in this respect, that, although the quality of the labour may be very good and the attendance may be regular while the new men are employed at the plant, still, they may not remain long.

One may have an applicant, who from investigation, is a very good hand and has all the characteristics desired, and after taking employment he may be regular in attendance, may work steadily and conscientiously, but after probably two months he leaves.

Suppose that 50 per cent. of the employees were to remain for only two months in the year, it could readily be appreciated that the labour turnover would be tremendous, and the losses due to the constant necessity of training new men colossal.

It therefore becomes a problem for the manager when he gets good men who are constant in their attendance to keep them in his employ, and the manager who does not fully appreciate the value of an old employee who is thoroughly familiar with every phase of his work is cultivating trouble for himself.

There are also, in dealing with this problem, fundamental principles on which one can act, namely,

1. *Make the Work Agreeable.*—It is well-nigh impossible to retain workers where the tasks they perform are inexcusably monotonous and distasteful. Many jobs are dirty and unhealthy simply because no attempt is made to make them attractive. Where smoke and fumes are offensive, there is no reason why provision should not be made for their removal. If ventilation is poor, it might be profitable in more ways then one to instal automatic ventilating systems. If the daylight is inadequate, or if the glare from artificial light is irritating, it might contribute to the contentment of the workers to establish indirect lighting arrangements. If the hours are excessive and the work requires intensive application, labour instability might be eradicated by allowing brief rest periods at certain intervals. If the tools and equipment are antiquated and it is annoying to use them, it might pay in terms of satisfied labour force to scrap the old tools and equipment and purchase new ones.

A great many manufacturing plants are going so far as to make a careful analysis of each job. The main idea, as is well known, is to study the contents of the job and find out what its requirements are both with respect to physical strength and mental capacity. When this is done, the results are tabulated and printed on a card in the form of job specifications. Then, when new men are employed,

they are selected so as to conform to these specifications and are adjusted to their positions in such a way as to make them contented with their surroundings and turn out the largest possible output commensurate with their wages.

2.—In addition to making factory work agreeable, it is necessary to *regularise it, or make it steady.*   Very few men want temporary jobs.   The great demand is for employment that is lasting.   Where workers hold positions that are insecure, they are in constant dread and their efficiency is greatly lessened.   Men working under such conditions resort to frequent changes of employment, and the result is much waste to both employers and workers.

It addition to this, I would say that every man should be given identity.   Do not let a man get lost in the plant.   Make him feel that he is being watched, that is, that his progress is being watched, that you are interested in him ; that it is your desire that he gets on and makes himself more valuable.

If he is not getting on, ask him what his troubles are, and give him an opportunity of voicing his opinions freely.

This last condition I mention should, of course, be done through the foreman in connection with the workmen, and where the foreman is concerned it should be done by his next superior, whoever that may be, and the manager through this chain (that is, the shift superintendent, the foreman, and his men) should make it his business to keep in touch with the men.   This may seem on first thought to be rather a colossal task, and some managers I know probably think it a waste of time, but in the author's opinion there is no organisation too large for this to be carried out quite easily and without taking a great deal of the manager's time.

Successful coping with this problem, of course, is strictly a question of organisation.   Where the plant is large, and there are large numbers of employees, it should be done through a special department, where, by means of simple forms and records of the work accomplished and the production, it is quite a simple matter to keep in touch with every man's progress.

5. *Machine or Mechanical Breakdowns.*

Although this trouble is probably one of the most frequent causes of loss of production, and certainly it is the most apparent, for when it occurs it is on the surface, so to speak, it can easily be seen and in my opinion is the least wearisome of the five which I have mentioned.

Machine breakdowns, whether occurring to the actual bottle machine, the air compressor, steam engine, electric generators or

motors, or mechanical parts of any apparatus, are, in probably nine cases out of ten, due to lack of foresight. Failure on the part of the man responsible to anticipate troubles either in the operation or in the upkeep of the particular machine, failure to see that spares for vital parts of the various machines are kept in store, and failure to keep all moving parts properly oiled and the machines clean, all of which bring us back to the human element and organisation.

It is the foreman's duty to impress thoroughly on such of his men that may be responsible for maintenance and upkeep of machinery the necessity of keeping machines clean and well oiled at all times, as well as to carry out any other special instructions that may apply to the upkeep or operation of any particular type of machine.

It is obvious from these general remarks, particularly appertaining to the various troubles that go to make up the losses of plant efficiency, that a great responsibility rests on the foremen, of whom there are many in a plant; and if the foremen have great responsibilities, then the manager has a greater responsibility in seeing that he has competent and capable foremen.

I was always very particular in the selection of a foreman when I was in a position where the responsibility of selecting them devolved on me, and I may give here some suggestions of what questions a manager might ask himself in selecting his foreman or when determining his capabilities.

First, is he honest in every way? Secondly, is he substantial, that is, dependable in an all-round and general way? Next, is he subject to the influence of other men in the shop? Is he prejudiced or narrow-minded? Who are his associates and what does he do with his spare time? Is he ambitious and does he feel that the work he is engaged in offers ample opportunities to make him anxious to treat it as his life work? Does or can he exert good influence over men, and can he talk forcibly, to the point and with conviction when necessary? Will he study his job and endeavour to perfect himself in the work, realising that there are many angles to it and many units that go to make up the whole? Last, but not least, can he control himself and thus permit his mind to function properly in times of dire stress or emergency?

As I stated before, I have only attempted to treat the subject of works organisation generally, and I sincerely hope that these little thoughts or suggestions that I have given will serve some useful purpose, or at least furnish a basis for useful discussion.

I know that all are quite as familiar with these things as I am, but sometimes we find when we have read an article or listened to some-one speaking on certain subjects, that thoughts or ideas are awakened which have been well-known to us but have been lying dormant;

and we find their resurrection very often both refreshing and beneficial, and I hope that what I have said here will have that effect.

DISCUSSION.

Col. S. C. HALSE said Mr. Moorshead had given them a most interesting paper, which had brought home to himself very much the things he had found on entering a glass works of no great size as compared with the big Government factory where his lot had formerly been placed and where there had been running for a good many years a well-established organisation. When in the Ministry, he was in touch with Mr. Webster Jenkinson, who told him, to his surprise, that before the war, to his knowledge, there were not more than 5 per cent. of the firms working in this country who had any system of costing at all. He was very much surprised, because in Government factories they had had systems of costing, very elaborate ones in some cases, dating back for many years before his time. He found that the system of costing used by other firms, as well as his own, had not very much relation to the cost, that is, always assuming that prices were based on the system of costing. Of course, if prices were not to be based on a system of costing, it was not very much good having one. After a good deal of experimenting, they discovered that they had very largely to work out a system of costing and then to guess the prices as far as they could in relation to what was being done by other people.

All the questions of labour Mr. Moorshead had raised must very much depend on the locality. He possibly had a very good selection. Speaking for himself, he was afraid that his factory was situated where the choice was not so good. In fact, they could not pick as they liked but had to put up with what they could get. If they began making delicate inquiries as to how and where the men spent their evenings, he did not know what would happen.

He could quite appreciate Mr. Moorshead's point, and that sort of attitude was undoubtedly the one adopted in the factories where he had worked previously, factories in which there was an opportunity of getting the best labour available in the district, and where they could offer what Mr. Moorshead said was so important, namely, a permanent job.

In regard to Mr. Moorshead's opening remarks, he told them that he had been assuming the plant to be a modernly-equipped and up-to-date one. However, the majority of manufacturers had not

got that huge advantage, but had to struggle in a good many ways with a plant that was not modern.

At his own factory some machines had been installed, and from them, by strictly attending to them daily, he thought they had got some very fine results.

The weekly conference could not be so valuable as a daily conference which included everybody really concerned in the output of their machines, namely, the chief in charge, the warehouse foreman, furnace manager, his assistant, and the works chemist. Manufacturers would find, as had been found at his own works, that by analysing the figures from day to day they increased their production very greatly, and they were able to trace very nearly every bottle dropped on to the conveyer. Perhaps this close investigation was too much to do, certainly for a large plant and probably for a small one, but when beginning the working of a new plant he was quite convinced the investigation was invaluable.

If one tried to apply the same method to an ordinary glass hand it did not work. An ordinary glass hand had rules and methods of his own, and as for getting the maximum out of a tank, he would not hear of working on Saturday or Sunday. That brought him (Col. Halse) down to the point where he feared they failed, namely, that the plant was not balanced. The tank was not balanced with the machines. If one possessed a certain sized tank, a certain output should be got from it. Unfortunately, if the tank was capable of feeding eight machines continuously, but the men would not work more than five days per week, there was no alternative but to put the manually operated machines out of action, and instal others.

Mr. J. H. STEELE wished to express his personal thanks to Mr. Moorshead for his very excellent paper. There was one thing he liked about the policy he put forward, namely, that he had introduced into his works a little spirit of freshness and taken away a good deal of the dryness of duty, and if they could only follow on the same lines as Mr. Moorshead they would find a new inspiration in their work.

The paper contained very many points of extreme interest for the ordinary manufacturer as well as for those in great undertakings such as Mr. Moorshead represented. As Col. Halse had suggested, they were not in a position in some districts to put into operation the policy that Mr. Moorshead had outlined.

He did not think, however, that the difficulties relieved them from the duty of attempting to create a new feeling throughout the works; co-operation between every man from the top man to the lowest man. This was an important duty, and he was very glad it had been emphasised so strongly. There were very great diffi-

culties inside the works, especially with the human element, in securing that interest which was so much needed. He himself had tried some of the methods set out. Sometimes they were received with enthusiasm, at other times with a great deal of suspicion, and he was continually endeavouring to get every man on the plant to understand that he was not just a cog in the wheel, and that the organisation depended as much on him, although he did not seem to be very important, as it did on a man who took some of the responsibilities.

One would like to see the form of *questionnaire* to which Mr. Moorshead referred as being used in securing the superior quality of labour mentioned. He did agree with Mr. Moorshead that the scientific character of the plant, the lay-out, and the machinery, all might be of the best and the latest, but one could not get the efficiency that was desired if the staff was not efficient.

Mr. F. F. S. BRYSON said the desirability of interesting a man in his work and also of getting him to know exactly why he performed certain operations was a very important point. He thought, in his paper, Mr. Moorshead had carried his policy down to the foreman, but did not seem to carry it further. It was highly essential that some form of training should be carried from the foreman to the workmen themselves. Possibly Mr. Moorshead could give us some information as to the method of doing this, as he thought more could be done in this direction than was being done at present.

Mr. E. D. J. ROBERTSON remarked that the Department of Glass Technology at Sheffield had encouraged local centre courses in the various glass-making districts. As a matter of fact, one of these classes had been held in the town from which he himself came. Although they found that the class as arranged under the Education Committee was not well attended, by carrying on the class in the works laboratory a good attendance had been obtained and a number of students had gone up for examination.

Mr. G. S. DUNCAN (*communicated*) : In ascribing to large labour turnover one of the causes of inefficiency in a works organisation Mr. Moorshead had directed attention to a subject which had not yet received the consideration which its importance demanded. How important it was could be gauged from the fact that an American investigator had estimated the cost of installing a new employee at £5 for an unskilled workman, and at £50 for a skilled craftsman. An English writer on the subject had put the average figure at £8 per head. Taking the latter estimate, and the comparatively low labour turnover of 50 per cent., the expense (on this account alone) to a factory employing 100 hands would be £400 per annum.

It would be interesting to know whether Mr. Moorshead had any

figures available as to labour turnover in the glass industry, and whether he had been able to form any estimate as to the average cost of discharging an employee and engaging another in his place. A paper by Mr. Moorshead at some future meeting of the Society on the whole subject of labour turnover would be welcome.*

MR. T. C. MOORSHEAD, replying to Mr. Bryson, said they did make it a point to instruct the men, but the instruction was given through the foreman; that is, by means of the foremen's meetings. They discussed carefully the instructions that ought to be carried to the men, and placed on the foreman the obligation of carrying these instructions to them. The foreman was held responsible for the results of his men and for keeping them fully informed. In addition to that, they had more open meetings. They did not insist on every employee coming to these meetings, where general talks took place, but they kept a careful record of those who did attend, and if they knew that any particular man or number of men continuously absented themselves, these men were asked the reason for doing so. One man might say he did not know anything about the meetings. This was the sort of man they were looking for, to get rid of. If a man was interested, he would attend the meetings; if he was not he would not. If he was not interested, they did not want him round the plant, and told him so.

Col. Halse in his remarks said that they did not all have modern plant and equipment. They had been fortunate in having them at Charlton, but he had said in his paper, if there was efficient manage-

* Meantime the following references are given for the benefit of members interested in the subject :—

(a) *A Report on the Causes of Wastage of Labour in Munitions Factories Employing Women.* By Major M. Greenwood. (Medical Research Committee. Special Report Series. No. 16. 1918. H.M. Stationery Office. 1s. 6d. net.)

(b) *A Statistical Study of Labour Turnover in Munition and other Factories.* By Gladys M. Broughton, M.A., Ethel M. Newbold, B.A., and Edith C. Allen. (Industrial Fatigue Research Board. Report No. 13. 1921. H.M. Stationery Office. London. 3s. net.)

(c) *Labour Turnover—Its Character, Causes and Cost.* By H. J. Brocklehurst, M.Eng. (*Cost Accountant.* July 1922. Pp. 57–65. Institute of Cost and Works Accountants, London. 1s.). This article gives an excellent discussion of the whole question.

(d) *Waste in the Hiring and Firing of Men.* By M. W. Alexander of the (American) General Electric Co. (Proceedings of the Employment Managers' Conference in 1917. Published by the Bureau of Labour Statistics, U.S.A. Whole Number 227.)

(e) *Steadying Employment.* By Joseph H. Willits. (Annals of the American Academy of Political and Social Science. May 1916.)

(f) *The Turnover Factory Labour.* By S. H. Slichter. Pp. xiv. + 460. New York and London. D. Appleton & Co., 1919. Price 15s.

ment, absence of modern plant was less severely felt.   An efficient manager would get a higher efficiency out of an absolutely old plant than an inefficient man would with a modern plant.   One could have the best designed plant or most modern machinery, but if a bad organiser were in charge of it the efficiency attained would be lower than in an old plant well managed.   It simply became a question of organisation and proper management.

X.—*Works Organisation.   Managing Men.*

By JOSEPH CONNOLLY.

(Contribution to the Discussion at Sheffield Meeting, April 18th, 1923.)

THE secret of human efficiency is interest in one's work.   This fundamental fact must ever be the basis of all panaceas for labour trouble.   The way to stimulate interest is to set a definite task for a worker to do in a given amount of time.   This is the plan followed in most of our schools, and it was this same principle that General Foch applied so successfully in the handling of the various fighting units of his army.   This scheme of setting a task, with a reward for its accomplishment, is in the author's opinion in accord with human nature.   A great deal of labour unrest results from foremen knowing less about industrial relations than some of their own workmen.   How can such foremen reconcile labour differences at their inception ?   Too often during periods of industrial strife these men are mere onlookers, when they might be efficient leaders and moulders of thought.   Frequently, when workmen are possessed of fallacies about industry, these misconceptions would be corrected if the under-officials were qualified to make adequate response to the inquiries of workers.

The average workman believes that most of his aspirations could be satisfied now, and with no increase in production.   He often asserts that the mere act of raising the selling price of a product will settle all his employer's difficulties.   In many instances, workmen are convinced that it is a distinct advantage to restrict output. How many foremen have an effective answer for such views ? In addition to engendering a reasonable and unprejudiced mental attitude on the part of the workers, managers and foremen should be instructed to report deficiencies in works organisation, and make every effort possible to discover causes of friction and unrest.

Recent years have witnessed the introduction of various plans that are designed to establish a condition of industrial democracy.

In the majority of cases where profit-sharing schemes have been inaugurated, they have failed because the employees were suspicious of the motives behind the plan. The common attitude of many workers may be described in the words, " Gi'e me mine now." Of course, some profit-sharing plans have succeeded.

Industrial conditions are improving, but losses through ignorance in management are still high. The nation's losses through absenteeism, if 7 per cent., or twenty-one days each year, are enormous. The fact is that idleness is a demoralising influence that decreases the efficiency of the workers. Steady employment is an acquired habit. In the event of workers absenting themselves, the firm has to bear an overhead expense with no return whatever. If a less competent workman takes the place of the absent employee, the result is a reduced output.

Better attention to lighting, ventilation, sanitation, clean workshops, level floors, and general welfare will materially reduce absenteeism arising from sickness and accidents. Doubtless there are several ways to increase industrial output by up-to-date equipment, but do not overlook the wonderful possibilities which lie in the scientific handling of men. The wise manager awakens the worker's interest by allowing him, as far as possible, to exercise self-choice in the matter of a job. All labour becomes drudgery when a person is compelled to do something he dislikes. Each unit of every business must eventually become a self-governing democracy. The only satisfactory future lies in providing a situation where both the human and the material factors will flourish together.

Imagination is more fruitful in producing efficiency in managers and happiness among the workers than either a good memory or reason. It takes imagination to be a successful manufacturer or manager or inventor. System, shrewdness, and economy make an ordinary success, but the power to see the unseen needs to be added to produce the highest achievements ; in a word, imagination.

1 MOORFIELD ROAD,
    PENDLETON, MANCHESTER.

XI.—*A Rapid Method of Testing the Durability of Glassware.*

BY H. S. BLACKMORE, VIOLET DIMBLEBY, B.Sc., AND
PROF. W. E. S. TURNER, D.Sc.

(Read at the Birmingham Meeting, March 21st, 1923.)

SOME time ago we were invited to express an opinion on tests outlined by L. Kroeber * for the purpose of ascertaining the suitability of glass for making ampoules. For the purposes of the test, the ampoule might be filled with one of the following solutions : (1) 1·0 to 2·0 per cent. of morpnine hydrochloride : (2) 0·5 per cent. solution of strychnine nitrate ; (3) 1·0 per cent. solution of mercuric chloride ; (4) a dilute solution of phenolphthalein ; (5) 0·1 per cent. solution of narcotine hydrochloride.

The ampoules, after being charged with one or other of these solutions, were to be heated in a steam steriliser for half an hour and examined either for development of a pink colour, in the case of the phenolphthalein, or deposition of a precipitate in the other cases.

The narcotine hydrochloride reagent was recommended as the best. We had ourselves not tested this reagent previously, although in a previous paper by one of us, † reference had been made to the use of the other reagents, especially in testing bottles which were to contain medicines or drugs. For medicine bottles, the tests suggested are eminently suitable, since medicines frequently contain salts of the alkaloids, and these are sensitive to the influence even of traces of alkali extracted from the glass with the consequent precipitation of the alkaloid itself.

Some preliminary tests indicated to us that the solution of narcotine hydrochloride was, as indicated by Kroeber, particularly sensitive, and it seemed that it might well be investigated with a view to constitute the basis of a simple test on other classes of glassware than ampoules.

For this reason, we have applied the test to a considerable number of different types of glass, the durability of which we had already previously determined, or the composition of which we knew, and could therefore estimate what the durability would be. Thus, we have carried out tests on some types of chemical glassware, on bottles and samples of tubing, and finally on a series of glasses of

* *Chem. Zeitung* 1914, **38**, 1196; *Schweiz. Apoth. Zeitung*, **59**, 369.
† W. E. S. Turner, this Journal, TRANS., 1919, **3**, 41.

graduated composition; and from a study of the results we have drawn the conclusion that the use of a solution of 0·1 per cent. narcotine hydrochloride does provide a test which can be carried out quickly and satisfactorily in any factory without requiring expensive or complicated apparatus. Further, it does not require any scientific knowledge or call for any calculation.

The Test.

The solution of narcotine hydrochloride is prepared by dissolving 1 part of the material in 1000 parts by weight of hot distilled water. The vessel in which the solution is made must be of chemical resistant glass or of other material which is not acted on by the reagent. Platinum is, of course, ideal, but is quite unnecessary. The vessel to be tested, a bottle, for example, is suspended in a water-bath and heated to boiling. When that stage is reached, 50 c.c. of the narcotine hydrochloride solution, which has also been heated to boiling point, are added and the mouth of the bottle is closed with a plug of cotton-wool.

The heating in the water-bath is continued and the appearance of the solution noted from time to time. If a cloudy precipitate appears within ten minutes, the glass is of unsatisfactory quality; if a precipitate begins to appear after ten minutes and increases during an hour, the glass is not sufficiently good to contain medical preparations, especially solutions of alkaloids. If minute needles appear in fifteen to twenty minutes but do not increase very distinctly in amount during an hour, the glass is of quite satisfactory durability. If there is no precipitation at all within an hour then the glass is quite durable.

It may be remarked that with some glasses we have tested there has been no deposition found even if boiled with the solution for an hour, followed by standing in the cold for twenty-four hours.

The bottle or other article to be tested must be cleaned for the test by a dilute solution of acetic acid followed by distilled water, and finally rinsed out with alcohol to remove the water and to assist rapid drying. It is an advantage, especially in the case of a thick vessel, for the drying to take place in the steam oven at 100°, as it can then be transferred at once to the bath of boiling water without cracking.

I. Tests on Chemical Glassware.

Four types of chemical glassware were included in the test. Nos. 1, 2, and 3 are of British make, one being a zinc borosilicate, another an alumino-borosilicate and the third a borosilicate of

similar type to miner's lamp glass.   Glass No. 4 is Kavalier's ordinary soda–lime–potash glass.

Table I shows the result of the test, and indicates that there is no precipitation or only the slightest possible precipitation when the glass is very durable, as with the chemical glasses included in this section.

TABLE I.

Extent of Precipitation of Narcotine Hydrochloride.

Time of contact. (minutes).	Beakers.				Flasks.		
	1.	2.	3.	4.	1.	2.	4.
10	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
20	,,	,,	,,	,,	,,	,,	,,
30	,,	,,	,,	,,	,,	,,	,,
45	,,	,,	,,	,,	,,	,,	,,
60	very slight.*	very slight.*	,,	?	,,	,,	,,
Verdict.	Very good.	Very good.	Very good.	Very good.	Very good.	Very good.	Very good.

II. *Tests on Bottles and Types of Known Durability.*

Included in this section were several glasses which, either from previous durability tests or from reputation, we could definitely regard as durable.   Thus, tests on powdered glass by boiling in water and other reagents had been made by us on glasses 5 and 6, whilst the autoclave test had been applied to bottles corresponding with No. 8.   The tests show these samples to be of satisfactory durability.   In the case of samples 9 and 10, the tubing was from reputable firms.   The composition, however, was not known to us.

In the case of the amber glass, No. 8, we would note that the composition was calculated from the batch and not derived by analysis.

Table II states the result of the narcotine hydrochloride test, and it will be seen that in no case was there any precipitation within forty-five minutes, and only a slight precipitation in two cases, namely, samples 7 and 9, at the end of one hour.   All the glasses were durable, therefore, as we expected from other tests, and the results accordingly gave us further confidence in applying the narcotine hydrochloride reagent.

* The precipitate was so minute that we are doubtful if it was the result of alkali from the vessel.   No precipitate whatever was obtained in the flasks, the mouths of which could be readily closed, and we are inclined to think that the very slight effects noted in the beakers after one hour were due to impurities floating in from the air through the spout.

TABLE II.

Tests on Bottles and Tubes of Known Durability.

		5.	6.	7.	8.	9.	10.
		Pale green mineral.	Pale green mineral.	Wide-mouthed.	Amber round.	Resistant tube.	Combustion tube.
Composition.	SiO_2	73·02	69·77	n.d.	71·04	n.d.	n.d.
	Al_2O_3	0·59	0·59	n.d.	1·20	n.d.	n.d.
	Fe_2O_3.........	0·18	0·78	n.d.	2·0	n.d.	n.d.
	CaO	9·56	8·08	High	12·0	n.d.	n.d.
	MgO	trace	5·42	n.d.	—	n.d.	n.d.
	Na_2O	15·55	15·16	n.d.	11·00	n.d.	n.d.
	SO_3	0·73	—	—	—	—	—
	MnO	—	0·20	—	3·0	—	—
Time.	10 mins.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
	20 ,,	,,	,,	,,	,,	,,	,,
	45 ,,	,,	,,	,,	,,	,,	,,
	60 ,,	,,	,,	Slight.	,,	Slight.	,,
	90 ,,	,,	,,	,,	,,	,,	,,
Verdict.		Very good.	Very good.	Good.	Very good.	Good.	Very good.

III. *Tests on Bottles of Known Composition.*

In the previous section we have dealt with glasses which had already been found by us, before the application of the narcotine hydrochloride test, to be of satisfactory durability. In this present section we show the result of tests applied to glasses which either from definite durability tests or from composition determined by analysis, or both, we knew to be unsatisfactory. Some of the bottles had been found previously to be altogether unsuitable for use as containers, whilst others of them were on the border-line, and could scarcely be regarded as satisfactory.

Here again the narcotine hydrochloride test gave us results which were in very close accord with our expectation in all cases.

Attention may be directed to the fact that lack of durability appears to depend rather more on the content of alkali than on any other factor. Thus, with sample 18, which contains as much as 8·74 per cent. of lime and 0·84 per cent. of alumina, the durability was not quite satisfactory, and the reason is to be ascribed to the presence of 19·16 per cent. of sodium oxide.

IV. *Tests on Glasses of Graduated Composition.*

Two series of glasses in particular were available for our test, namely, soda–lime–silicate glasses and soda–alumina–silicate glasses. Of these two sets, the former has already been tested for durability

TABLE III.

Tests on Bottles of Known Composition.

	11.	12.	13.	14.	15.	16.	17.	18.
	Flat, white.	Flat, pale green.	Plain medical.	Small tablet.	Amber round.	Fancy white.	Feeding bottle.	Flat, pale green.
SiO₂ ...	72·93	72·42	75·40	68·58	74·70	72·84	70·90	70·68
Al₂O₃ .	0·92	1·17	n.d.	0·38	1·16	1·10	1·27	0·84
Fe₂O₃...	0·07	0·22	n.d.	0·18	0·14	0·10	0·21	0·17
CaO ...	3·38	4·85	4·20	5·34	5·04	7·68	7·70	8·74
MgO ...	0·26	0·27	—	0·12	0·08	0·41	trace	0·06
K₂O ...	—	—	—	—	1·98	—	—	—
Na₂O .	21·56	20·66	20·40	25·22	16·60	16·86	19·10	19·16
Sb₂O₃...	0·59	—	—	—	—	—	—	—
Sulphur & carbon.	—	—	—	—	traces	—	—	—
SO₃ ...	—	—	—	—	—	0·90	—	—
As₂O₃...	—	—	—	—	—	—	0·75	—
Se	—	—	—	—	—	—	—	trace
10 mins.	H.	H.	H.	H.	H.	D.	S.	S.
20 ,,	V.H.	V.H.	V.H.	,,	,,	S.	I.	,,
45 ,,	—	—	—	—	—	I.	,,	I.
60 ,,	—	—	—	—	—	,,	,,	,,
90 ,,	—	—	—	—	—	,,	,,	S.I.
Verdict.	V.poor.	V.poor.	V.poor.	V.poor.	V.poor.	U.A.	U.A.	Not quite satisfactory.

(The left labels "Composition." brace the upper rows and "Time." braces the mins. rows.)

H.—Heavy ppt. V.H.—Very heavy. D.—Doubtful. S.—Slight. I.—Increasing. U.A.—Unfit for alkaloids.

by several methods and detailed accounts of the variation of durability with composition have been published from this laboratory.*

In the case of the soda–alumina–silicate glasses, whilst tests have been carried out they have not yet been published, but we can, at any rate, compare our results with those of the narcotine hydrochloride.

It will be seen that, in this series of glasses, which correspond approximately with the general formula $6SiO_2,xCaO,yNa_2O$ where $x + y = 2$, that up to the point at which the lime content is about 4·5 per cent., the glass is of very poor durability. Distinct improvement takes place in the next two members of the series, but a really satisfactory state is not reached until the glass contains 8 per cent. of lime.

These results tally closely with those previously obtained by boiling the glasses in water and in various other reagents. From our earlier tests, we had previously regarded glass No. 23 as on the

* Cauwood, Clarke, Muirhead, and Turner, this Journal, TRANS., 1919, **3**, 228; Dimbleby, Muirhead, and Turner, *ibid.*, 1922, **6**, 101; Hodkin and Turner, *ibid.*, 1922, **6**, 291.

border-line, and here again with the narcotine hydrochloride it occupies a similar position. It might be used without harm for a number of purposes, but, for safety, undoubtedly the next higher glass in the series is to be recommended.

Table IV.

A. *Soda–Lime–Silicate Glasses.*

		19.	20.	21.	22.	23.	24.	25.	26.
Composition.	SiO₂ ...	74·08	74·07	73·78	73·18	74·41	74·99	74·96	74·93
	Na₂O .	23·00	21·50	20·78	19·38	17·20	16·00	14·88	13·02
	CaO ...	2·61	3·81	4·50	6·26	7·45	8·16	9·36	11·68
	MgO ...	trace	trace	0·15	0·21	0·24	0·26	0·28	0·31
	Al₂O₃ .	0·21	0·28	0·38	0·58	0·30	0·31	0·42	0·38
	Fe₂O₃ ...	0·15	0·14	0·19	0·61	0·40	0·09	0·16	0·17
Time.	10 mins.	H.	H.	F.H.	Nil.	Nil.	Nil.	Nil.	Nil.
	20 ,,	I.	I.	S.I.	S.	S.	,,	,,	,,
	30 ,,	,,	,,	,,	,,	,,	,,	,,	,,
	45 ,,	,,	,,	,,	,,	,,	,,	,,	,,
	60 ,,	,,	,,	,,	,,	No. inc.	S.	S.	,,
Verdict.		V.poor.	V.poor.	Poor.	Fair, but U.A.	Fair.	Good.	Good.	V.good.

B. *Soda–Alumina–Silicate Glasses.*

		27.	28.	29.	30.	31.	32.
Composition.	SiO₂	74·30	73·30	72·05	72·19	72·27	71·56
	Na₂O	22·68	22·20	20·62	18·79	16·61	15·28
	Al₂O₃	2·72	4·25	6·85	8·96	10·71	12·69
	MgO	trace	trace	trace	trace	trace	trace
	CaO	0·08	0·02	0·12	0·08	0·21	0·21
	Fe₂O₃..............	0·07	0·10	0·08	0·08	0·07	0·10
Time.	10 mins.	H.	H.	Nil.	Nil.	Nil.	Nil.
	20 ,,	I.	I.	S.	,,	,,	,,
	30 ,,	,,	,,	S.I.	,,	,,	,,
	45 ,,	,,	,,	,,	,,	,,	,,
	60 ,,	,,	,,	,,	,,	,,	,,
Verdict.		V.poor.	V.poor.	Fair.	V.good.	V.good.	V.good.

It will be seen that up to 4·25 per cent. of alumina these glasses are not very durable. The glass with 6·85 per cent. of alumina may again be regarded as a border-line case, but with the 8·96 per cent. the glass becomes quite satisfactory, despite the presence of 18·79 per cent. of sodium oxide.

General Conclusion.

The general conclusion, therefore, which we have drawn after examining all the preceding glasses, is that the narcotine hydro-

chloride test applied under the conditions outlined above is quite
a satisfactory method of testing rapidly the durability of glass
towards water.

DEPARTMENT OF GLASS TECHNOLOGY,
   THE UNIVERSITY, SHEFFIELD.

DISCUSSION.

PROF. TURNER said that he thought members had now got a
rather closer understanding of the caution which often appeared
on medicine bottles, "To be shaken before taken," for it had been
demonstrated that, owing to the alkali extracted from the glass,
the drugs in solution might be precipitated. They would all be
anxious to congratulate Miss Dimbleby on being the first lady to
address the Society, and he hoped that she would again appear,
and that other ladies, too, would come forward from time to time,
especially if they all handled their subjects with the clearness
and conciseness the speaker had evinced that afternoon.   He would
like to emphasise that, not only was the test just described a good
qualitative one, but it should enable them to draw the line in a
series of glasses between bad, poor, and good, and particularly so
in the case of the soda–lime glasses of differing compositions.
Three years ago he emphasised the need for keeping up the lime
content to 8 per cent. or more, if possible, and the alkaline oxide
content down to certainly not more than 16, or at the very outside
18 per cent., and the line that was drawn on that occasion was
confirmed quite definitely by the reagent they had been considering
that afternoon, namely, narcotine hydrochloride. He thought the
adoption of these working limits in glass factories would obviate
such lengthy and elaborate papers as they had seen appearing in
their American contemporary, discussing methods by which glass
containers could be treated in order that they might withstand
storage.   The only cure was to make a better glass, and the
durability of the glass could be readily gauged by this particular test.

MR. J. G. HILL inquired whether the test in question had been
applied to ordinary beer glasses, which, of course, were made from
lead, as well as to the particular glasses to which reference had
been made in the paper.

MR. F. G. CLARK said that he thought the paper should be
extremely valuable to manufacturers, if they would only take
notice of it. He was wondering whether the test could be made
into a quantitative, as well as a qualitative, one. Would it not
be possible for the cloudy deposits to be weighed or measured in
some way ? And with regard to the narcotine hydrochloride,
would it be possible to keep it in lead bottles instead of having to

provide those necessarily expensive silica bottles which had been referred to; if not, could gutta-percha bottles, or something of that sort, be used?

MISS DIMBLEBY, in reply to Mr. Hill's question, said that no definite tests had been carried out on lead glasses as yet. The reason was that they did not happen to have any suitable lead glasses available at the time of the tests in the laboratory. But she did not see why such tests should not be made and reported on later. With regard to Mr. Clark's questions, she was not at all sure whether any measurements of the deposits could be carried out that would be sufficiently trustworthy and warrant the time and trouble that they would involve. As to the storage of the solution, she did not think this should involve any real difficulties. Although it rapidly attacked nickel and other metals and gave a deposit, it did not attack platinum. That, however, was too expensive. Lead had not yet been tried. Personally, she would not recommend storing the reagent as a solution; it should be made up specially whenever it was intended for use. She thought that any good chemical resistant glass as employed for flasks and beakers could be used as a container for the solution for the comparatively short time that it was necessary to hold it in the carrying through of a test. She did not see why an ordinary high-lime glass should not be suitable for the purpose, provided it had already been tested by narcotine hydrochloride and found satisfactory.

PROF. TURNER added that, although the discussion had centred, to some extent, around containers, he saw no reason why window glass or any other type of glass in sheet, rod, or lump form should not be tested by placing the sample inside another glass which was known to be sufficiently resistant. One would find that practically all the really good chemical glasses on the market were suitable for the purpose of a container, and if a manufacturer had not available a chemical glass, and did not wish to buy it specially, if he made a good manganese amber glass he would probably find that it would answer the purpose.

XII.—*A Note on the Suitability of Quartzose Residues for Glass Manufacture.*

By W. J. REES, B.Sc.Tech., F.I.C.

THE residues or tailings from the crushing of auriferous quartz for the extraction of gold are highly siliceous and as they are a waste product of considerable bulk, it appeared possible that they might be utilised as " sand " in the manufacture of common glassware in districts contiguous to ore treating plants where supplies of free sand are not cheaply obtainable.

At the suggestion of Dr. W. F. Smeeth, of the Department of Mines and Geology, Mysore State, India, the author in 1919 examined the residues from the crushing plants in the Kolar Goldfield, Mysore, with a view to determine their suitability for this purpose, and he is indebted to Dr. Smeeth for permission to publish the results of the investigation.

The Kolar sand contains a good deal of hornblende and other iron-bearing minerals in addition to the metallic iron impurity derived from the stamps.

A bulk sample of the sand was obtained, and half of it was treated in a large magnetic separator by Messrs. G. T. Holloway & Co. for the removal of as much as possible of the ferruginous matter. The analyses of the crude and cleaned samples are as follows :

	Crude sand.	Cleaned sand.
Silica	72·59 per cent.	84·70 per cent.
Alumina	5·36 ,, ,,	5·73 ,, ,,
Iron and iron oxides	6·14 ,, ,,	1·87 ,, ,,
Titanium oxide	2·90 ,, ,,	0·23 ,, ,,
Lime	6·20 ,, ,,	3·85 ,, ,,
Magnesia	5·00 ,, ,,	2·05 ,, ,,
Potassium oxide	1·21 ,, ,,	1·14 ,, ,,
Loss on ignition	0·91 ,, ,,	0·64 ,, ,,
	100·31 ,, ,,	100·21 ,, ,,

The grading analysis of the two samples is as follows :

	Crude sand.	Cleaned sand.
Retained on 30 mesh sieve	nil	nil
,, ,, 40 ,, ,,	0·5 per cent.	0·5 per cent.
,, ,, 50 ,, ,,	1·5 ,, ,,	1·5 ,, ,,
,, ,, 60 ,, ,,	1·5 ,, ,,	1·5 ,, ,,
,, ,, 70 ,, ,,	3·0 ,, ,,	3·0 ,, ,,
,, ,, 100 ,, ,,	13·0 ,, ,,	22·0 ,, ,,
Passed 100 ,, ,,	80·5 ,, ,,	71·5 ,, ,,
	100·0 ,, ,,	100·0 ,, ,,

The greater part of the ferruginous impurities are seen to be concentrated in the finer grades of the sand. The sand is much finer than any free or prepared sands normally employed in glass manufacture, but its chemical composition indicated its possible suitability as the basis for the production of durable common glass.

A series of glasses was made in a laboratory furnace, the weight of batch melted in each case being sufficient to give about 2 lb. of glass. The necessary quantities of ground limestone and soda ash (together with a little nitrate of soda) were added to the sand to give glasses approximating to the general formulæ $Na_2O,CaO,6SiO_2$ and $Na_2O,CaO,5SiO_2$. In all cases the melting was very rapid, there was very little frothing, and the glasses " plained " readily.

The crude sand gave a very dark greenish-brown glass. It was noticeably " tough," there being no fracture of the melts, even with fairly rapid cooling. This glass should be quite suitable for bottles (such, for example, as stout bottles) or jars where colour and transparency are unimportant.

The cleaned sand gave a pale green glass. It was not quite so " tough " as the glass made from the crude sand, and it is possible that the higher content of titanium oxide in the latter in association with the high alumina content has an influence on this particular property. The iron content of the glass was too high for satisfactory decolorising. This glass should be quite suitable for the manufacture of common bottles, jars, acid carboys, etc.

Larger meltings of glasses with each grade of sand were then made. They founded and plained readily at 1350° and were very workable and mellow at 1000—1100°. It was evident from these trials that glass could be made from either the crude or the cleaned sand which would be quite suitable for bottle or jar-making by either hand or machine processes. As would be expected from the chemical analysis of the sand, the glasses were free from any tendency to devitrification.

The mechanical and chemical properties of articles made from the glasses were quite satisfactory and compared favourably with those of articles made from normal bottle-glass in this country.

This investigation indicated therefore that residues such as those from the Kolar Goldfield would be a satisfactory raw material for use in the manufacture of common glassware when freedom from colour is unessential.

THE UNIVERSITY,
    SHEFFIELD.

XIII.—*The Year in Review in the World of Glass Technology.*

By Prof. W. E. S. TURNER, D.Sc., F.Inst.P.

THERE is usually but cold comfort to be obtained by looking back on the doings of a year which, on the whole, was disappointing so far as the general position of the glass industry is concerned.   Nevertheless, the clearer view which a retrospect affords is often useful in directing a wise course for the future.

Most manufacturers have some idea of the state of the trade in our own country.   The hopes that were entertained at the beginning of the year were scarcely fulfilled.   The one section that can be said to have done satisfactorily is that devoted to making pressed glassware.   At the other end of the scale, optical glass-makers and the bottle industry have both been down in the dumps, and it is unfortunate that the bottle branch, which more than any other has reorganised its methods and spent large sums on new equipment, should have to wait still longer to see the fruit of its efforts.

On the whole, the condition of the industry was a shade better than that in the previous year (1921).   This conclusion is not only derived from the writer's general acquaintance with the industry, but also from the figures for exports and imports in 1921 and 1922 summarised in Tables I and II.

In this country, we have no organisation which collects statistics of production.   I am reminded of this by a recent reply in Parliament of the President of the Board of Trade.   Some other countries are able to keep a check on their productivity, and one can only hope that manufacturers will soon realise the great advantage of similar statistics in our own country.

The figures for exports and imports, if they may be taken in any sense as a measure of production, show distinctly better results in 1922 as compared with 1921, and although the values do not differ greatly for the two years, this is due partly to the decline in prices diminishing the value of the 1922 products.   It is satisfactory to note that the quantities of imports in 1922 were only about 60 per cent. of those in 1913, and it is obvious that the shortage of trade in the industry cannot be ascribed to an overwhelming flood of foreign supplies, although it is a fact, on the other hand, that the ratio of imports to exports was greater in 1922 than in 1913. It is likely, however, that no great losses were sustained by the glass bottle industry by the failure to obtain the application, early in 1922, of the Safeguarding of Industries Act, Part II, to this

TABLE I. Value (£). *(Braced figures in the 1920 columns are combined totals for the grouped categories.)*

Types of Glassware	Exports 1913 £	Exports 1920 £	Exports 1921 £	Exports 1922 £	Imports 1913 £	Imports 1920 £	Imports 1921 £	Imports 1922 £
Scientific (except tubing and rod)		702,790	75,127	60,671		1,271,428	101,857	64,793
Tubing and rod (for all purposes)			16,745	8,320			30,839	17,223
Illuminating			80,591	49,613			396,931	405,475
Machinery			79,415	43,461			4,748	1,356
Optical (other than worked elements, e.g., lenses)			71,068	29,063			7,770	1,260
Domestic and fancy (including cooking utensils, table glassware, and ornamental glassware)			232,153	170,696		2,404,287	1,403,457	1,436,122
Plate and Sheet	605,847	1,547,848	1,047,815	1,229,792		2,280,350	1,354,957	1,547,210
Bottles and Jars	1,207,918	857,837	528,790	457,203	814,032	2,500,913	1,288,239	963,801
Unenumerated		102,334	42,822	39,509	2,634,488	49,730	34,505	37,051
Totals	£1,813,765	3,210,809	2,174,526	2,088,328	£3,448,520	8,506,708	4,623,303	4,474,291
Ratio Exports/Imports	0.526	0.377	0.472	0.467				

TABLE II. Quantities. *(Braced figures in the 1920 columns are combined totals for the grouped categories.)*

Types of Glassware	Exports 1913 Cwt.	Exports 1920 Cwt.	Exports 1921 Cwt.	Exports 1922 Cwt.	Imports 1913 Cwt.	Imports 1920 Cwt.	Imports 1921 Cwt.	Imports 1922 Cwt.
Scientific (except tubing and rod)		45,975	1,849	913		648,267	4,801	4,697
Tubing and rod (for all purposes)			5,196	5,101			99,281	150,266
Illuminating			7,783	5,058			879	133
Machinery								
Optical (other than worked elements, e.g., lenses)			2,664	1,087			680	119
Domestic and fancy (including cooking utensils, table glassware, and ornamental glassware)			12,063	14,192		731,965	345,324	441,065
Plate and sheet		515,018	354,663	546,246			586,128	870,415
Unenumerated		9,247	3,935	5,829		10,636	8,432	10,723
Totals Cwt.	935,086	570,240	388,153	578,426	2,681,113	1,390,868	1,045,525	1,477,418
Bottles and Jars (Gross)	974,465	553,544	310,768	339,321	1,923,571	2,135,842	1,043,971	1,180,150

branch of the trade; although doubtless, when trade is very limited and machinery standing idle, it is tantalising to have to part with any orders and see them supplied from abroad.

Unemployment appears to have undergone no marked change throughout the whole of the year, there being fluctuations but no marked improvement; but, fortunately, on the other hand, no marked worsening. Table III states the figures which have been extracted from the *Labour Gazette*.

TABLE III

Total Unemployment and Systematic Short Time. Glass Trades (Excluding Optical, Scientific, etc.)

| | | | Total unemployment. | | Systematic short time. | |
| | | | | | Short time workers claiming | |
		Estimated No. of work-people.	No. of unemploy-ment books remaining lodged.	Percent-age un-employed.	unemploy-ment insurance benefit.	Percentage of systematic short time.
1921.	Dec. 30	43,360	9,503	21·9	2040	4·7
1922.	Jan. 31	43,360	9,079	20·9	2417	5·6
,,	Feb. 21	44,060	9,093	21·0	2385	5·5
,,	Mar. 27	43,540	9,670	21·9	2458	5·6
,,	Apr. 24	43,540	9,680	22·2	2358	5·4
,,	May 22	43,540	9,433	21·7	2276	5·2
,,	June 26	43,540	8,228	18·9	1526	3·5
,,	July 24	43,540	8,202	18·8	1143	2·6
,,	Aug. 21	43,540	9,266	21·3	852	2·0
,,	Sept. 25	43,540	8,815	20·2	676	1·6
,,	Oct. 23	45,630	9,004	19·7	489	1·1
,,	Nov. 20	45,630	9,100	22·1	—	—
,,	Dec. 18	45,630	8,658	19·0	—	—
1923.	Jan. 22	45,630	9,120	20·0	—	—

People with capital have also been unwilling to embark on new glass ventures. The Company Registrations in glass and china, as disclosed in Table IV, show that the position on the whole was very much the same as in 1921.

TABLE IV

Company Registrations at Somerset House.

GLASS AND CHINA.*

| | Public Companies. | | Other Companies. | | Totals. | |
	No.	Capital. £	No.	Capital. £	No.	Capital. £
1920	11.	2,743,000	54.	1,212,600	65.	3,955,600
1921	2.	195,000	37.	303,200	39.	498,200
1922	1.	65,000	52.	429,300	53.	494,300

* From Lists compiled by Messrs. Jordan and Sons, Ltd., Chancery Lane, London, W.C. 2.

Nevertheless, on the whole, there has been quite a definite feeling throughout the industry that more stable conditions have been reached and that the period of gloom will be dissipated, even if the clouds rolled away only very slowly.

In that spirit a number of firms have still gone forward with improvements and reorganisation of equipment, and will undoubtedly reap the benefit in due course.

We shall doubtless be a little more contented with our lot when we learn that a number of other countries have not done very much better. In France, the industry as a whole has had many trials, and the condition of trade has fluctuated considerably. During the early part of the year the question of the reduction of wages caused some general disturbance, and until April, after these adjustments had been made, there was little improvement. The window glass industry was rather upset by the sales which the Government was making of a large stock of window glass purchased from abroad towards the end of the war. In the autumn, distinct improvement appears to have taken place in all districts except the factories in Champagne and Bordeaux, the products of which had previously been disposed of to the export wine trade.

In Belgium, at the end of January, 1922, 3,488 out of 19,035 employees were registered as without work; that is to say, about 18 per cent., whilst a further 3 per cent. were on short time. This condition was very similar to that of our own industry. At the beginning of the year, orders were also short and the question of wages was still being discussed. We learn that the reductions in wages in this country had led the Belgian makers also to demand reductions from the Belgian workers in the early spring; but the glass workers themselves felt that any reductions exacted would fall rather hardly on them in comparison with the workmen in other trades, since whereas their existing wages were three times those in 1913, workers in most other trades were getting four times as much. In the autumn, distinct improvement set in, the mirror glass factories working to about 75 per cent. of their normal capacity, and the window glass factories also being fairly busy. The hollow-ware branch was said to be well employed, mainly owing to considerable orders having been received from England. In the manufacture of crystal glass also, a steady but very definite improvement occurred, and there was a shortage of good craftsmen. By December, the prospects had improved still further, the mirror industry in particular then working at full capacity. On the other hand, the bottle industry was quiet, and orders were short throughout the year.

In Holland, we learn that at the end of 1921 only three bottle factories remained in operation, and in April no improvement had occurred, thirteen bottle factories out of sixteen being still shut

down. There appears to have been no considerable improvement throughout the year.

Of other European countries, Italy, Denmark, and Norway have certainly not been doing well. Their glass industries are comparatively small, but they have reflected the general conditions of bad trade. In Spain, trade has fluctuated very considerably. In the early part of the year the production had dwindled to about 50 per cent. of the working capacity—a capacity which was not very great, since the equipment of most factories was obsolete. In the summer, the activities seem to have been stimulated very greatly, but subsequently died down again towards the end of the year.

The two most important glass-making countries on the Continent of Europe, namely, Czecho-Slovakia and Germany, have had rather different experiences from one another. In the former, the improvement in the country's external credit has had the unfortunate result of making export almost impossible, with disastrous results. Already at the beginning of the year the export industry of Gablonz had dwindled considerably; business with Germany had for the most part disappeared, whilst orders for other countries were becoming fewer owing to the rise in the value of the kroner. I have dealt elsewhere * with the general position in Czecho-Slovakia and need, therefore, only say that since the early autumn, when works began to close down in wholesale fashion, the position has become still worse and the outlook is very dark, unless the leaders of the industry can arrive at some method of cheapening production very considerably, to achieve which, in any case, must call for very considerable sacrifice all round.

Whilst every country in Europe has been suffering, the industry in Germany has, generally speaking, been very active. In January, the *Keramische Rundschau* reported : '' The trade of the glass works is everywhere very active. The factories in Rhineland are engaged almost entirely on export orders, so that their home connections can for the most part obtain no goods.'' The increase in the value of the Czecho-Slovakian kroner had automatically shut off imports.

In the early spring, trade in Thüringen was stated to be so good that a number of glass-makers in the south of this district had decided to set up for themselves, whilst glass blowers in Steinheid were also considering the idea of erecting their own factory. Again in April the *Keramische Rundschau* reports : '' The glass industry in the month of April was abundantly provided with orders.'' In October, orders were still keeping factories busy. The only difficulties which factories everywhere encountered were in obtaining

* *The European Commercial,* Vienna, September 23, 1922; this Journal, TRANS., 1922, **6,** 274.

supplies of raw material, particularly soda, and fuel, which in some districts was very scarce. Considerable quantities of coal were imported from England, whilst the Bavarian industries were having to obtain coal from Czecho-Slovakia.   The prosperity of the industry has been leading to certain important developments and it is understood that the group with which Stinnes is working have made very large purchases in America of the rights in automatic glass-making machinery covering bottles, bulbs, and tubing, and propose to erect huge works in which the new plant will be installed.

Our friends in America have by no means had the prosperity of Germany, but conditions can scarcely have been as bad as with us, and soon after the summer a very definite improvement took place. 1921 was a comparatively lean year as compared with 1919, the complete statistics showing a diminution of 28·6 per cent. in the total number of persons engaged and 26·5 per cent. in the value of the products (Table V).

TABLE V

Statistics for the Glass Industry of the United States.

	1921.	1919.	Per cent. decrease.
Establishments	328	371	11·6
Persons engaged :			
Total	59,705	83,650	28·6
Firm members ...	50	60	
Salaried employees	4,979	6,076	18·1
Wage earners	54,676	77,520	29·8
Salaries	$12,290,000	$13,364,000	8·0
Wages	$67,562,000	$87,527,000	22·8
Value of products ...	$212,593,000	$261,884,000	26·5

In the first half of 1922 improvement seemed to be mainly in the air, with little of substance to show, but evidently a condition preparatory to material improvement.   The large companies were not doing at all badly, however; thus, the Owens Bottle Co. and its subsidiary companies made net profits during the first six months of the year, to June 30th, of $1,929,153 as against $1,147,568 in the same period for 1921.   Although these profits were distinctly less than in 1920, they were some 25 per cent. better than in 1919.   The American Window Glass Co. also showed a surplus on August 25th, 1922, of $7,905,944 as against $8,372,575 on August 26th, 1921, the latter including part of the boom year.   The Libbey Owens Sheet Glass Co. also paid satisfactory dividends and was still extending; thus, in the early part of the summer a new factory was started at Shreveport, Louisiana, comprising three tanks each of 1,000 tons capacity and each having two sheet glass drawing machines,

whilst another factory was announced in the early autumn for Toledo with a total capital of \$6,000,000. There was no summer stop in 1922, and in September *The Glass Industry* in a leading article pointed out that the revival of trade, about which there had been so much discussion without any very definite evidence, had now actually begun.

Turning to the technical developments of the industry, we find cause for greater satisfaction in that brains have been still actively at work, even if commercial production has been restricted. The pages of our own Journal help us to measure research activity in glass technology, and we have reason for pride in the position held by this country. The Glass Research Association has also published during the year three numbers of its *Bulletin* containing several important papers. In America, the stream of papers so copious during 1918 to 1920 in the journals of the Ceramic Society and the Optical Society seems to have nearly dried up. Activity finds its outlet, however, in discussions such as those in the *Glass Industry* and in the new feature of the American Ceramic Society, namely, the *Bulletin*, whilst inventors are just as eager as ever. From Germany there has come no contribution worth mentioning to our knowledge of glass, but attention has been concentrated on the saving of fuel; and the Wärmetechnische Beratungsstelle der Deutschen Glasindustrie has been inculcating methods of firing designed to achieve this object. The activities of this body also led, in July, 1922, to the founding of the Deutsche Glastechnische Gesellschaft (German Society of Glass Technology).

In general research, the subject which appears to have been most prominent is that of the durability of glass. No fewer than eight papers on this subject appeared in our own Journal during the year, five being from the Department of Glass Technology of the University of Sheffield. Further, the British Glass Instrument Research Association has issued a report on the subject of durability, and three papers were published in American journals. One of the American papers discussed methods by which bottles and jars kept in storage shall not deteriorate or show filming. There is only one way, in the opinion of the writer, namely, to make better glass. If the weight of the evidence in the numerous papers is not yet sufficient to indicate the importance of the subject, manufacturers should not lose sight of the fact that in this country in 1922 an important and costly law case was fought round this subject of the durability of glass.

On the subject of optical glass, Weidert * in Germany, has summarised the experience of his firm, at Sendlinger, during the war, whilst Peddle † has summarised the more valuable scientific advances

* *Sprechsaal*, 1921, **54**, 423.   † *Trans. Opt. Soc.*, 1921—1922, **23**, 103.

made in this country in our knowledge of the properties of glass and optical glass in particular. On the theoretical side, the investigations of Lebedeff * deserve more than passing interest. They were carried out apparently in ignorance of somewhat similar work in America, and led the author to some interesting speculations on the change of polymorphic form in silica which might conceivably occur in silicate glasses in the neighbourhood of 575°. The theory scarcely receives support from the fact that sodium borate glass shows absorption and evolution of heat during heating and cooling. It is, however, interesting to note that Lord Rayleigh † has discovered evidence of slight crystalline structure in fused quartz, although possibly in this case due to residual crystalline matter not completely broken down. In the writer's Department some measurements have been made by Mr. A. R. Sheen to test if amorphous substances like pitch and resin showed absorption or evolution of heat like silicate glasses, but the results were negative. In this connection one may recall the comparison, by Filon and Jessop, ‡ of glass and celluloid in respect of residual strain after load. The latter showed sign of strain, the former did not; and it appears likely from these and our own results that amorphous inorganic and amorphous organic substances may differ in behaviour just as there are well marked differences between inorganic and organic colloids.

Of subjects more applicable to glass manufacture I may note the papers on the decolorising of glass in tank furnaces by selenium which have appeared in our own Journal.§

Of new types of glass, the only one of note produced commercially during the year has been the so-called unbreakable glass of Messrs. Kavalier, Sazava, Czecho-Slovakia. The exaggerated accounts given of the properties of this glass have rather detracted from its real merits in the minds of those who are really able to judge; but it will be found, as it becomes better known, that it has valuable qualities and marks a further development in the melting and manufacture of resistant glass.

The improvement of furnaces has attracted the attention of a number of workers. It is not easy to appraise at their correct value most of these improvements, which may or may not be merely ideas on paper. The novel features which have appealed to the writer are four. The first is the small tank furnace designed by Bellamy ‖ for the melting and working of lead glasses. The second is the

* *Trans. Opt. Inst. Petrograd*, 1921, **2**, No. 10.

† *Proc. Roy. Soc.*, 1921, [*A*], **98**, 284.

‡ *Ibid.*, 1922, **101**, [*A*], 165.

§ A. Cousen and W. E. S. Turner, this Journal, TRANS., 1922, **6**, 168; F. W. Adams, *ibid.*, p. 205.

‖ *J. Amer. Cer. Soc.*, 1922, **5**, 157.

proposed construction of a glass tank with wooden sides in which cold water flows so as to solidify the layer of glass adjacent to it and thus form a trough of solid glass.* This idea, in one form or another, namely, obtaining a tank which, for all intents and purposes, is a tank made of glass, has been discussed in the United States for some years, and Hurley's patent formulates one idea on the subject. One might be permitted to ask, in connection with this scheme, how the first layer of glass would be brought into contact with the wood with the view of forming the trough ?

A new method of charging a tank furnace, especially in order to make possible the melting of glass of high quality, is outlined in a patent by R. Good and the Hazel Atlas Co., U.S.A.,† and consists in having charging cones let down through the crown of the furnace.

Patents for proposed improvements in pressing and blowing machines have been numerous, but no very striking development is to be recorded. The installation of machines proceeds steadily in this country, despite the trade depression, and hand labour in factories making containers is a rapidly diminishing quantity, most of it being engaged on medical and the so-called flint glass bottle trade. Devices for transferring charges of glass from tank furnaces to machines have also been numerous, but again no displacement of the better known forms seems to be threatened. In this country the two forms of feeding device most widely used are the Hartford-Fairmont and the Rankin.

The drawing of sheet glass offers problems for fertile minds. Flowing methods of forming sheet glass, including the method of discharging glass on to a casting table, as at the Ford Plate Glassworks, and methods of drawing sheet glass downwards as well as upwards have all received much attention. The downward drawing process, has, I understand, in the case of Shield's process, already reached the stage at which it may be commercially exploited, and promises well. It is interesting also to recall that whereas the Libbey-Owens sheet glass process has invaded Belgium from the States, the Fourcault process of drawing sheet, which had already spread from Belgium to Japan, England and Czecho-Slovakia, has, in 1922, been taken up actively in the United States and a strong company formed to exploit it.

In closing this review there are two things for which I should like to appeal. The first is for the still wider employment in the industry of persons of technical training. As I go about the country I am constantly met with troubles which have their origin in ignorance of glass-making operations. For the difficulties which arise are due to one of two causes, the first to the fact that precise knowledge on

* U.S.A. Pat., No. 1390614.   † U.S.A. Pat., No. 1421210.

some point does not exist, the second because, although the knowledge exists, it is not appreciated and applied.   The solution of the first type requires more and ever more research.   The second kind, however, calls either for a change of attitude or change in *personnel* in the industry.

During these times, when costs have to be brought down to a minimum, it would seem almost unnecessary to urge that all those who are in charge of departments in a factory should know their job absolutely and the reason for doing things.   Unfortunately, this is far from being the case.   We are getting on the right road in the industry in this country, but we can make progress still more quickly if the heads of firms will see that appointments to posts are made on the sure basis of knowledge instead of on the precarious rule of thumb basis, often miscalled experience.   There are young men now available who, if given their chance, could do a great deal towards improving the state of affairs in many factories.

The second appeal I have to make is for the still freer and wider discussion of problems facing the industry, technical and industrial. We have much to rejoice over in the remarkable position this country now holds in research in glass technology.   There is ample room, however, for more contributors of papers, and indeed, the Council desires that any member who has ideas to contribute shall have a free opportunity to do so.   I am quite definitely of the opinion that those who actively participate in the publication and discussion of technical results are themselves all the better for doing so.   They frequently derive more out of the process than their hearers.   Moreover, publication by manufacturers is worth considering as a means of advertisement alone.   Customers who are made acquainted with the fact that the representatives of a firm contribute papers and take part in discussions at scientific societies are bound to have their respect for and confidence in the firm increased.   I am quite sure that if the success of a firm depends on character—and surely it does—then if a firm has the enterprise sufficient to enter into scientific and technical discussions in public, it is reasonably certain that its enterprise will also be exercised in building up a reputation for its products and for its good name in the world of industry and commerce.

DEPARTMENT OF GLASS TECHNOLOGY,
    THE UNIVERSITY, SHEFFIELD.

XIV.—*Stainless Steels from the Point of View of the Glass Industry.*

By W. H. HATFIELD, D.Met.

(Head of the Brown-Firth Research Laboratories, Sheffield.)

(Read at the Sheffield Meeting, January 17th, 1923.)

THE development of stainless steel represents a distinctive new departure in special steels. The presence of a high percentage of chromium, combined with the treatment which the material receives in manufacture, is responsible for producing an alloy which, in a variety of circumstances, remains passive. The result is that, at the ordinary temperature, normal atmospheric corroding influences fail to attack it, but what is more important to the glass manufacturer is that it retains its strength abnormally well at higher temperatures when compared with ordinary steels and, incidentally, does not scale to anything like the extent of the ordinary iron and steels. The latter two characteristics appear to make it particularly valuable for a number of purposes in the glass industry. For instance, glass-blowing irons, rolls, pins, moulds, pivot points, ball races, screws, gland brushes, belt conveyors, lehr chain pins, knives for glass cutting, brushes for the bottoms of glass moulds, gathering irons, muffle lehrs, and air- and steam-pipes.

The application of this steel is greatly facilitated owing to the fact that the industrial development has taken place sufficiently for the steels to be now obtained either in the form of forgings, castings, bars, sheets, wire, or tube.

Stainless steel is the name applied to a range of steels which belong to the iron–carbon–chromium alloys, the chromium in all of them ranging from 12 to 14·5 per cent. The percentage of carbon, manganese, silicon, and other elements is controlled within desirable limits. As a result of research and works experiment, there are now available other stainless steels than the original one, which was produced for cutlery and allied purposes and was rustless only in the hard condition.

The material is now supplied in a high tensile and machinable condition ; it simply requires machining to shape, and is satisfactorily rust-resisting without further treatment.

There is also a malleable stainless steel which has been evolved for the purpose of supplying a rust-resisting material, chiefly in sheet form, which can be easily deformed in the cold, be hammered, pressed, or drawn into the requisite shape, and requires only polishing to produce a good surface. Further, there is the so-called

" stainless iron," which is a stainless steel in which the carbon content is reduced to a very low percentage.

All these steels are manufactured by the electric process of steel manufacture, and require and receive the careful subsequent manufacture which is necessary in the case of alloy steels.

The Strength of Stainless Steel as shown by Mechanical Tests.

The strength of stainless steel, as determined on the tensile testing-machine, varies according to the composition and to the degree to which the temper is drawn, from above 100 tons per square inch breaking-load in the hard condition, down to 30 to 40 tons per square inch when fully tempered.* A specimen series of figures, obtained with a steel containing 0·30 per cent. of carbon, is given in Table I. The whole of these test-pieces were oil-quenched from 950° and then tempered to the temperatures indicated.

TABLE I.

Specimen Series of Tests.

Tempered.	Yield point tons/ sq. in.	Max. stress tons/ sq. in.	Elon- gation per cent.	Reduc- tion of area per cent.	Impact.	Brinell hardness number.
100°	101·6	107·1	2·0	1·4	—	477
200	100·4	106·7	3·0	4·9	—	477
300	86·6	102·7	7·5	22·9	—	450
350	87·8	104·3	10·0	30·5	—	450
400	96·0	105·0	12·0	36·2	15, 6, 10	477
500	98·5	107·1	15·0	44·0	6, 6, 10	450
550	72·8	79·7	17·0	50·3	24, 23, 20	325
600	51·4	60·5	20·0	55·8	25, 28, 26	263
650	43·3	52·3	22·0	62·6	69, 70	235
700	41·3	49·1	26·0	64·7	70, 69, 61	223
750	36·6	45·9	30·0	70·7	79, 80, 83	202

The interesting feature about these figures is that the hardness and tensile strength were substantially maintained up to a tempering temperature of 500°; higher tempering temperatures then resulted in a thorough tempering of the material down to very low tensile figures. The results which were obtained, in this instance, from the Izod impact test are also included in this table, and it will be seen that, as the material was softer, the impact value went up to a very high figure.

* These lower figures correspond with malleable stainless steel or stainless iron.

TABLE II.

Mechanical Properties of Stainless Steel.

	50-ton condition	100-ton condition
	oil-quenched at 950°.	
Condition.	Water quenched at 650°.	Tempered at 250°.
Tensile.		
Elastic limit, in tons/sq. in.	30·0	—
Yield point, tons/sq. in.	39·8	95·0
Maximum stress, tons/sq. in.	49·02	106·7
Elongation, per cent.	22·0	7·0
Reduction of area, per cent.	55·0	29·5
Torsion.		
Yield in tons/sq. in.	26·07	50·3
Probable maximum stress	32·9	57·4
Degrees twist	478°	69°
Izod impact, in foot-pounds	48	8
Arnold, reversals	168	152
Stanton, blows	4,281	1,651
Sankey, in foot-pounds	1,440	1,240
Hardness.		
Brinell hardness number	217	444
Shore hardness number	35	64

Apart from the malleable form, stainless steel is almost invariably used either in the hardened and slightly-tempered condition, in which it has a tensile strength of about 100 tons per square inch, or it is used in the well-tempered condition, when it has a tensile strength of about 50 tons. The mechanical properties in these two conditions have been exhaustively determined in laboratory tests, full details of which will be found in Table II.

Exhaustive fatigue tests have also been carried out on this steel in both these conditions, with the following interesting results. The tests were performed on the Wohler rotary fatigue testing-machine. The test-piece was rotated horizontally at 1,500 revolutions per minute, with a load hung from one end. This load was changed for each test until a load was reached which just produced the stressing which the material would bear without rupture during 10 million revolutions. The results of the tests on stainless steel, in comparison with those obtained from an ordinary structural carbon steel, are given in Table III.

It will be seen that mild steel can be stressed alternately in tension and compression to only between 11 and 12 tons per square inch, if the material is to survive 10 million revolutions. In the 50-ton (well-tempered) condition, stainless steel will carry alternate tension and compression stresses of 21 tons per square inch, whilst in the 100-ton (knife temper) condition, this material will stand 32 tons per square inch. It will be realised that, as the test-piece

revolves under the load in this form of test, the whole of the periphery in the plane of high stress is alternately in tension and compression during each revolution.

TABLE III.

Comparative Tests with Stainless and Ordinary Carbon Steel.

Tons per square inch.	Structural carbon steel No. of revolutions.	50 ton M.S. Stainless steel. No. of revolutions.	100 ton M.S. Stainless steel. No. of revolutions.
11·7±	10,000,000	—	—
13·5±	3,247,000	—	—
15·3±	1,720,000	—	—
17·1	520,900	—	—
21·0	—	10,000,000	—
21·6	100,300	—	—
22·5	—	5,046,000	—
25·5	6,650	—	—
30·0	—	—	10,000,000
32·0	—	—	10,000,000
35·0	—	—	450,400

TABLE IV.

Mechanical Strength of Stainless Steel at High Temperatures.

Temperature.	Structural Carbon steel.			Stainless steel in the well-tempered condition			Stainless steel (knife temper).		
	M.S. tons per sq. in.	Elongation per cent.	Reduction of area per cent.	M.S. tons per sq. in.	Elongation per cent.	Reduction of area per cent.	M.S. tons per sq. in.	Elongation per cent.	Reduction of area per cent.
Ordinary	27·2	38·0	61·0	49·02	22·0	55·0	109·0	7·0	16·0
300°	32·5	23·2	55·8	49·0	30·0	58·0	108·3	8·8	13·0
400	25·2	37·2	68·5	43·5	21·0	56·0	101·5	4·0	6·6
500	20·0	38·0	73·0	35·5	22·5	65·0	87·0	8·8	27·5
600	12·5	48·0	86·0	21·7	31·2	88·7	32·2	19·2	70·1
700	6·8	56·0	93·0	13·8	33·0	89·5	14·15	32·8	72·8
800	4·0	65·0	96·0	6·54	69·6	98·0	6·80	71·0	98·0

As regards Young's modulus, it is of interest to state that experiments have shown : $E = 13,500$ tons per sq. in.

The Mechanical Strength of Stainless Steel at High Temperatures.

Stainless steel maintains its strength at high temperatures to a much greater degree than ordinary structural steel, and may, therefore, be employed with advantage where parts have to withstand stress at temperatures above the normal. Some of the tests recently made are stated in Table IV.

Hardness as Affected by Increasing Temperature.

By means of an impact Brinell instrument, the Brinell hardness numbers, noted in Table V, have been obtained.

TABLE V.

Brinell Hardness Numbers.

Temperature.	50 tons per square inch condition.	100 tons per square inch condition.
15°	235	440
100	212	420
200	190	414
300	160	345
400	130	360
500	110	345
600	100	175
700	85	89
800	70	70

Notched-bar Tests.

Experiments indicate that the energy absorbed in the notched-bar impact test is not substantially modified until temperatures approaching 600° are attained. Above this temperature, the values increase.

Resistance to Scaling.

In comparison with ordinary carbon steels, stainless steel resists scaling to a marked degree with increasing temperature. Tests performed up to 1,000° on mild steel, alloy steels, tungsten steels, and stainless steel showed that the stainless steel scaled less than any of the others.

The temper colours produced at much lower temperatures form an analogous phenomenon to scaling, and it is well known that when hardened tool-steel is tempered, the originally bright surface goes through a series of colours. During this process of colour change with increasing temperature, the skin of the steel becomes seriously affected when visible red heat is attained. Stainless steel responds in a very different manner, and up to temperatures of 800°, the effect on the surface is confined to the colour effect only. The same temper colours obtained during tempering, in the case of stainless steel, correspond with much higher temperatures than in the case of carbon steel.

Polishing, Grinding, and Finishing of Stainless Steel.

A clean metallic surface is necessary for the best rust-resisting results. The ordinary methods of preparing steel surfaces should be

employed. It should be pointed out, however, that grinding should always be done with water. If, by an abrading action, the temperaature of the surface is unduly raised, the stainless properties are locally affected by the scorching effect thus produced. For the best results, the surface should always be as good as can be commercially obtained. Nevertheless, it is not necessary to have a highly-polished surface for the material to be rust-resisting, provided all scale and pit-marks are eliminated.

Hardening and Tempering.

As regards the heating and cooling curves of the iron–chromium–carbon series of alloys, it will be quite clear that variations in the percentages of the different elements present have a profound influence. It may, however, be taken that the critical points on heating occur over a range extending from 820° up to 900°, and it is, therefore, essential in hardening to heat to the temperature at which one can be sure that the solid solution is formed. As a result of much experiment, it is found that the best temperature to heat to is 950—1,000°. After attaining this temperature, the material may be quenched in oil, and will then be satisfactorily hardened, provided the carbon is not unduly low. As regards tempering after hardening, it will be found that the hardened stainless steel is not tempered and softened by reheating until temperatures of 500° and above are reached, and, therefore, in order to put the steels into a machinable condition it is desirable to heat them to a temperature of at least 750°.

Where the steel is being put into service in the hardened condition, tempering at 180—200° is quite sufficient to take out the internal stresses left by the quenching operation without materially softening. When considering, however, the heat-treatment of any of these stainless steels, it is desirable to obtain specific instructions for each type of material.

It may here be recorded that the so-called " stainless iron," owing to its low carbon content, does not harden up to any considerable extent. The stainless steels, owing to their carbon and chromium content, air-harden readily; but in the case of the " stainless irons " with their low carbon content, this air-hardening effect is so small that small forgings may be made and yet, even in the forged condition, the material may be machined. It should, however, be specifically noted that this statement relates only to the very low-carbon types of material.

Microstructures.

If microsections are cut, polished, and etched, and examined under the microscope, it will be found that magnifications of at least 500 diameters are necessary to obtain really useful information, and this fact indicates the very fine type of structures obtained. In the soft condition it is found that the microstructure consists of a chromiferous ferrite matrix through which are distributed the particles of double carbide of iron and chromium. This is illustrated in Fig. 1. In the hardened condition the structure consists of a solid solution of carbides of iron and chromium in chromiferous iron, but generally there is still present a certain amount of free double carbide, as shown in Fig. 2.

When the hardened condition is tempered, a very close, fine structure is obtained, as shown in Fig. 3, which structure is the result of the decomposition by heat of the solid solution *in situ*.

General Physical Properties.

In the range of stainless steel manufactured, the physical properties vary to a considerable extent. The values obtained from the various types are as follows :—

Coefficient of expansion from 0—500°, 0·000012—0·000013.
Thermal conductivity. 0·0363—0·0466 c.g.s. units.
Electrical resistivity. 56·6—77·7 microhms per cm.
Maximum permeability. 75—810.
Permanent magnetism. Remanence 6,500 with a coercive force of 58—remanence 11,300 with a coercive force of 7.
Specific heat. 0·115—0·121.
Specific gravity. 7·61—7·738.

Having briefly reviewed in a general way the properties of the various types of stainless steel, a number of uses in the glass industry will be obvious to those interested. Apart from apparatus for glass production and manipulation directly, the engineering side should be considered, and in cases where resistance to corrosion or heat effects are called for, stainless steel will be found of great service. Such purposes are exemplified by pump rods, turbine blades, valves, annealing boxes and trays, and similar examples.

BROWN-FIRTH RESEARCH LABORATORIES,
        SHEFFIELD.

FIG. 3.

FIG. 2.

FIG. 1.
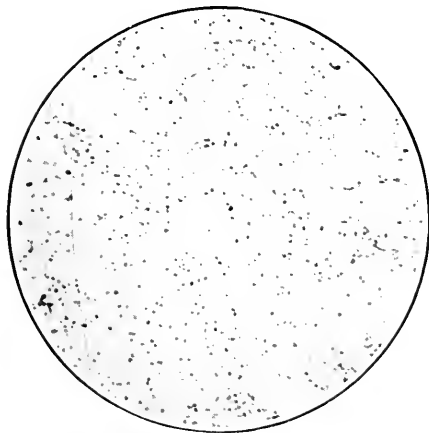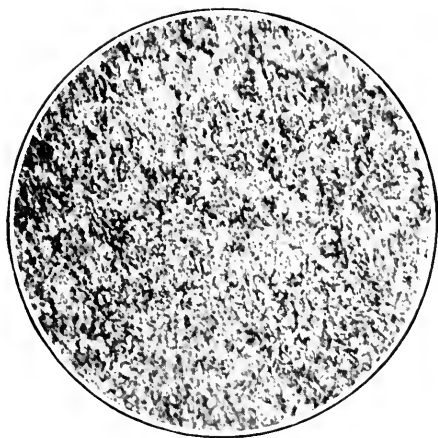
Discussion.

Prof. W. E. S. Turner said they were very grateful to Dr. Hatfield for his paper. If his talk on the subject had been brief, it was, at least, a lucid description of stainless steel.

There were a number of ways in which this steel appealed to him, and he might add that he had been thinking about the subject for some time. Some three or four years ago there were some attempts made to use nichrome for the noses of blow-pipes. Not very much progress had been made with that material; possibly it was not brought sufficiently to the attention of glass manufacturers as a body. At Sheffield, in the last twelve months, they had had one or two noses of stainless steel put on the blow-pipes with results which seemed to be wholly satisfactory. Moulds certainly seemed to be another useful field for stainless steel, not only because of the non-scaling properties at the temperatures at which moulds were used, but also, it seemed to him, because one very desirable feature was the fine character of the grain obtained with this material, which could not be obtained with the ordinary cast iron. One knew that in considering the merits of various types of material for moulds, say wood, brass, and iron, a better finish was certainly obtained with a brass than with the ordinary iron mould. Here now, it seemed to him, was a material capable of yielding a very fine, close-grained surface and should be capable not only of resisting scale, but also of giving a very much better finish to the goods blown in the mould. One other possible use had occurred to him, and he would like Dr. Hatfield's opinion on it, namely, the possibility of using stainless steel for light plates in the construction of muffle lehrs, such as were now coming into use extensively. The temperature inside might run round about 500° or 600°, outside possibly 800°, or 900° at most locally. This seemed to him to be another field well worth considering. The durability of refractories was always a source of some difficulty in construction work, and if one could get something which, although distinctly dearer, would have a very much longer life, then it would be worth while considering. He had attempted, not so much to discuss this paper, as to enter into the spirit of Dr. Hatfield's attempt to open up a talk on this subject, and to make suggestions. He hoped that other members present would have something to say suggestive of additional uses.

Mr. J. H. Davidson asked, in the case of blow-pipes, could the stainless steel be welded on to the ordinary iron blow-pipe? Could a nose be made of stainless steel and could it be welded by an ordinary blacksmith with ordinary intelligence and ordinary tools?

If stainless steel took a high polish, it might come in handy for moulds, and it might very well do without pasting. Another thing, there was the iron kettle used in the glass industry for ladling, in connection with which the chief difficulty was the iron-rust which might scale off into the glass. After ladling molten glass into cold water, and allowing the kettle to stand for a few days, the effect on the iron was very marked. Would it be possible to line a kettle with stainless steel? Again there was the question of the parison- and blow-moulds used in connection with automatic machinery. Would it be necessary to have the whole mould solid, or would it be sufficient to have an internal casing of stainless steel where the glass actually came into contact with the mould? The " growing " of the cast iron upset the mould and very often spoilt the accuracy of the glass-maker's work. It would be rather an expensive business to have the whole mould of stainless steel, but if an internal casing could be applied to the mould this might overcome the difficulty.

DR. W. H. HATFIELD : Why were parison moulds so heavy? Was it not due to the fact that they were made of cast iron?

MR. J. H. DAVIDSON : It was a matter of heat reduction. Incidentally it would be interesting if Dr. Hatfield would give his opinion as to the conductivity of stainless steel as compared with cast iron.

DR. W. H. HATFIELD : The conductivity of stainless steel was less than that of cast iron, roughly about a third.

MR. W. C. SNOWDON asked if the stainless steel would withstand battering such as would be entailed in the crushing of glass.

MR. R. HEMINGWAY said that in the opening and shutting of ring-, blow-, and parison-moulds, the latter had to withstand a considerable amount of knocking. Would stainless steel withstand this knocking? With the average iron ring-mould used to-day, it had not had a great deal of wear before it began to leave a nasty mark on the glassware. If stainless steel would reduce this trouble it was going to be a very valuable product.

MR. MILTON ASQUITH said he would like to know what was the price of stainless steel as compared with cast-iron. This was a very important point, and to make any calculations of the economy in using the material one would like to know the relative prices of cast iron and stainless steel.

MAJOR V. F. GLOAG had used stainless steel a great deal in connection with acids. Nitric acid had no effect on it, but sulphuric acid attacked it. That was a point he would like to mention when considering its use in a glass works, for instance in a gas producer, where one encountered sulphur dioxide in the gas. He believed,

however, that a stainless cast iron could now be obtained. He would like to know if that was actually a fact.

MR. GUY SIMPSON said that although the cost of making a ring-mould in stainless steel might, perhaps, not be extravagant, one had also to consider what would happen if moulds got damaged—and occasionally they did. What would then be the cost of re-melting? Would it be possible to get the mould recast or to get a good price for the old metal? If not, the cost would be very heavy. Although on feeder parts of the automatic machines and on blow-pipes the stainless steel might not corrode, it might corrode where it came into contact with gas, as Major Gloag had suggested. This would be rather awkward. He had had some experience of a large number of bottles being spoiled through pieces of iron corroding and dropping into the feeder. Where this occurred in connection with automatic machinery, a great deal of time and labour was entailed. With regard to the moulds, he was inclined to think that the principal item was, not the cost of the material used in the mould, but the amount of work that was put into it.

DR. W. H. HATFIELD said he much appreciated the discussion, which had really brought out some essential points and he would try to deal with one or two of them.

He was very much interested in Prof. Turner's experience in connection with blow-pipe noses. He himself had had some experience in this connection, and although it could not be considered as conclusive, it pointed in the same direction, and it would appear that the material would be very useful for that purpose. With regard to the point Prof. Turner raised as to the advantage to be gained by a metal with a good surface, that was a very good point and he might have brought up with him a mirror in stainless steel. Mirrors were actually produced for scientific purposes out of this material, and it was quite a habit to send stainless steel to different universities for that purpose. Several firms also were actually producing mirrors from this material.

With regard to the light plates for muffle lehrs, which had to resist a temperature of 500° or 600°, he thought the material would do very well. After all, they were comparing it with ordinary mild steel plates, and it was not a case of absolute resistance, but rather of relative resistance. They knew that under those conditions 12 to 14 per cent. of chromium had a tremendous influence in prolonging the life of the material of the steel.

In reply to Mr. Davidson's question as to whether stainless steel could be welded by an ordinary smith, with ordinary intelligence and ordinary tools, it was necessary to be rather more quantitative as to what was meant by ordinary intelligence and ordinary tools.

There were smiths and smiths. Speaking generally, however, an ordinary smith with an ordinary hearth could not do this. At the same time, at many works this welding was a course of daily procedure. It was usually done by electrical means. In this way, stainless steel could be joined to stainless or to ordinary steel without any difficulty at all. He would rather not give a more direct answer to the question, as it depended on the skilfulness of the smith.

Mr. Davidson had suggested that the moulds might not need pasting. Although he did not quite understand the technical significance of this question, he imagined that there would be no protection to the surface of the mould but this would not be needed if a proper surface were put on it in the first place.

As to whether a kettle could be lined with stainless steel or made entirely of this material, he would say that it would be quite possible to supply either.

Someone suggested in the discussion that glass moulds must necessarily be heavy. He (Dr. Hatfield) was a metallurgist and knew little about the glass industry, but they might take it from him that glass moulds were heavy. He would advise them to see whether, by the use of new metals, they could not introduce a lighter mould. This would be an advantage in many ways. If one started off on the hypothesis that the abnormal weight which glass moulds at present possessed was not really necessary, he thought they might achieve something.

In reply to Mr. Snowdon's remarks, the material would certainly withstand crushing, particularly if it was in its best condition.

In reply to Mr. Hemingway, stainless steel would stand wear and tear in regard to the opening and shutting of moulds. Its properties were just those required to withstand a certain amount of ill-usage. Major Gloag had spoken of the influence of sulphurous oxides. The stainless steel hitherto available would not resist sulphurous oxides in a wet atmosphere, or in a dry atmosphere. Stainless steel was, however, only one of the steels of a whole series now being developed to withstand the action of various media. In his (Dr. Hatfield's) laboratories, researches showed that quite a number of valuable alloys could be compounded, not all of them necessarily commercial, but one of them certainly commercial, did resist sulphuric acid. He would send Major Gloag a sample to try.

With regard to the economic side of the problem, seeing that he was a scientific man, they would scarcely expect him to discuss prices. After all, he would remind them that it was the ultimate price in which they were interested. One must divide service into price to arrive at the real cost. In a general way, stainless steel was not a cheap steel, but its price was not prohibitive for general

application in those industries where its special properties made its application desirable.

In regard to the price of scrap, he hoped they would spare him from replying to that question.   In any case if they did get a reply he was afraid they would be rather disappointed.

The Effect of Various Constituents on the Viscosity of Glass near its Annealing Temperature.

By S. English, M.Sc.

Discussion.

Mr. F. Twyman (*communicated*): I have read with great interest the paper by Mr. English on " The Effect of Various Constituents on the Viscosity of Glass near its Annealing Temperature." * The correlations established by him between constitution and viscosity should be of inestimable value in every industry concerned with the working of glass in the softened condition.

It is gratifying to see extended the line of work initiated by me in 1915 and 1916, and in part described in this Journal † in 1917, namely, the measurement of the temperature variation of the viscosity of glass in the annealing range, and I am glad to know that Mr. English's results so closely confirm the applicability of my approximate equation $M = k2^{\theta/8}$, or as Mr. English finds $M = k2^{\theta/9}$.

I think anyone reading Mr. English's paper without consulting the reference he gives would be left with the impression that the method of finding the annealing temperature of a glass by measuring its viscosity at various temperatures was first described by Messrs. Littleton and Roberts in 1920.   The following extract from my paper of 1917 cited above will make it clear that this was not the case :

" It is in this way that the general law of change of viscosity with temperature which I have mentioned has been established.

" From this general law, and a few observations carried out on any particular glass in the apparatus, as briefly outlined above, one is able to determine the temperature at which a particular degree of annealing will take place in any specified time without distortion of the object.   I call this temperature ' the annealing temperature.'

* This Vol., Trans., p. 25.   † Trans., 1917, **1**, 61.

" We will follow out the complete course of such a procedure," etc.

A complete case was worked out in the paper.

This method of determining annealing temperatures was worked out by me in 1915 for Messrs. Chance Bros. & Co., Ltd., for the only works then making optical glass in this country, and my apparatus and method were in use at that works from early in 1916 onward during the whole of the war. The same works also largely utilised with good results an accelerated cooling curve, which I suggested to them at the same time (early in 1916), in which the rate of cooling was at each temperature proportional to the viscosity.

The circumstances in which the experiments were conducted precluded their complete publication, although they were communicated to the Ministry of Munitions, until the publications of observers in America subsequent to my 1917 paper had appeared, which made it seem not worth while to publish the experiments *in extenso*. I trust, therefore, that I may be allowed this opportunity of placing on record this statement of prior work.

Mr. S. ENGLISH (*communicated reply*): I have read Mr. Twyman's interesting communication, and am glad that he has mentioned, although all too briefly, some of the work he did during the years 1915 and 1916, work which, although not published, was applied successfully in the manufacture of optical glass during the war.

With regard to the suggestion that my paper may lead a reader to the conclusion that Littleton and Roberts were the first to use the determination of viscosity as a means of fixing annealing temperatures, it must be admitted that such an interpretation is possible. I am well aware of Mr. Twyman's demonstration of the close relationship between the variation of viscosity with temperatures and the annealing temperature of a glass, and of the passage he quotes from his paper in this Journal for 1917. Also, in conjunction with Dr. Turner, I again directed attention to the relationship between viscosity and annealing in a paper published in this Journal for 1918, and showed how annealing temperatures may be fixed on an experimental scale or on a works scale by comparative viscosity determinations. However, in the present paper, prominence was given to Littleton and Roberts's work because they gave actual experimental data for the comparative mobility of a glass from which the rate of change of mobility with temperature could be deduced, and it was this factor, namely, dM/dT, in which I was more particularly interested.

XV.—*The Physical Properties of Boric Oxide Containing Glasses and their Bearing on the General Problem of the Constitution of Glass.*

By S. ENGLISH, M.Sc., and Prof. W. E. S. TURNER, D.Sc.

IN previous papers, attention has already been directed to the influence which the addition of boric oxide has on the rate of melting and working of glass, on its lampworking properties, its tendency to devitrification, and its general durability. Numerical data which would make possible a strict comparison of the variation of these properties with the composition were not given to any considerable extent, the effects discussed being considered rather qualitatively than quantitatively.

In the case of the annealing temperature, however, it has already been shown by us in a further paper that the addition of boric oxide in two series of sodium-borosilicates led certainly in the one case, and most probably in the other, to a rise of annealing temperature to a maximum value, after which there was a decline.

We now propose to describe the results of measurements on three other properties, namely, the thermal expansion, the density, and the refractive index (including the dispersion). We shall see that in all these cases there are noteworthy effects which, except in one isolated instance to be referred to later, have not previously been noted * during the study of the relationship between the physical properties and the composition of glass.

The Coefficient of Expansion.

The use of boric oxide in the development of glasses of low thermal expansion has been one of the most notable features in glass technology in the past forty years. Winkelmann and Schott associated with this oxide a thermal expansion factor less even that that of silica, the factors for the cubical coefficient of expansion deduced by them being $0 \cdot 1 \times 10^{-7}$ for each 1 per cent. of boric oxide and $0 \cdot 8 \times 10^{-7}$ for the same amount of silica. These relative values have always seemed to us to be open to some question, and it is particularly strange that this ratio should subsist if, as Winkelmann and Schott believed, the thermal expansion of glass is an additive

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* E. Zschimmer, *Zeitsch. Elektrochem.*, 1905, **11**, 629. Since writing the above, we have found that Schaller, Abegg's "Handbuch der anorg. Chem.," 1909, III., **2**, 273, states that the addition of boric oxide to an alkaline silicate increases the durability to a maximum, and subsequently, with further additions, decreases it. No data were given.

function of the chemical composition. For, whereas the actual cubical coefficient of expansion of fused quartz is only 0·0000015, that of fused boric oxide is 0·001308, an extraordinary difference, if Ditte's * determination of the latter figure is correct.

The usually accepted factors of Winkelmann and Schott also look suspicious when we examine the results of the determinations, by R. Riecke and W. Steger,† of the thermal expansions (linear) of materials used for glazes or enamels. Starting out with the silicate ${0·3CaO \atop 0·7PbO}0·2Al_2O_3,2·5SiO_2$ and replacing the SiO_2 in seven stages until the substance ${0·3CaO \atop 0·7PbO}0·2Al_2O_3,2·5B_2O_3$ was obtained, the linear thermal expansion rose regularly from 535×10^{-8} to 627×10^{-8}; whilst substituting the SiO_2 by B_2O_3 in ${0·3CaO \atop 0·7PbO}0·3Al_2O_3,3SiO_2$ in seven stages, the values rose continuously from 462×10^{-8} to 630×10^{-8}. These results are quite contrary to what might have been expected. Moreover, the greater the amount of silica the smaller the coefficient of expansion, and the greater the proportion of boric oxide the more expansible the glass.

Undoubtedly, however, in the case of commercial glasses, it would appear that boric oxide addition has been associated with the reduction of thermal expansion ; but the subject seemed to us to bear closer systematic investigation than has hitherto been given to it.

For the purpose of our tests, we had available fifteen of the boric oxide-containing glasses, the general properties of which have been described in an earlier paper from this laboratory. In the series containing approximately 20 per cent. of Na_2O, it was not possible to draw tubing when the glass contained more than 30 per cent. B_2O_3, and unfortunately, for this reason, the complete series was broken at a very interesting stage. In the 10 per cent. Na_2O series, the range was restricted at lower concentrations of B_2O_3 owing to difficulty in melting the glasses,‡ but eight glasses were available for the test.

The actual expansion determinations were made in much the same manner as in previous similar investigations by us, but the

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* A. Ditte, *Compt. rend.*, 1877, **85**, 1069; *Ann. Chim. Phys.*, 1878, V., **13**, 67.

† *Sprechsaal*, 1914, **47**, 578, 585.

‡ Attempts have been made, so far without success, to obtain specimens of the glasses varying in composition from 90 per cent. $SiO_2,10Na_2O$ to 80 per cent. $SiO_2,10Na_2O,10B_2O_3$. The first of these was nearly, but not quite, melted at 1500° in an open pot. Our chief difficulty in obtaining usable specimens has been due to devitrification on working in the case of the glasses of highest silica content.

weight of mercury expelled from the dilatometer was the quantity used as the basis of calculation, and not the difference before and afterwards of the dilatometer and contents. The very slight difference in procedure was necessitated by the action of water on the glass dilatometer when submerged in the thermostat, some of the boric oxide glasses being far from durable.

In Table I are given the values obtained, and side by side with them we quote those calculated on the basis of Winkelmann and Schott's factors.

TABLE I.

The Coefficient of Linear Thermal Expansion.

Temperature range 25·0° to 90·0°.

A. *Glasses containing approximately 20 per cent. Na_2O.*

Per cent. B_2O_3.	$\alpha \times 10^8$		Per cent. B_2O_3.	$\alpha \times 10^8$	
	Obs.	Calcd.		Obs.	Calcd.
0·00	915	876	14·45	837	856
4·46	840	878	18·84	805	820
8·28	817	838	28·83	814	835
11·29	813	837			

B. *Glasses containing approximately 10 per cent. Na_2O.*

12·45	578	596	31·26	542	502
18·71	498	537	36·17	557	509
21·81	497	546	42·33	570	502
25·82	521	558	46·07	606	526

Fig. 1 shows the results of the determinations expressed graphically and we see at a glance that on increasing the proportion of boric oxide present in the glass the coefficient of expansion diminishes to a certain point and then increases; in other words, there is a minimum thermal expansion produced by a certain addition of boric oxide and after that, instead of being beneficial, the further addition is harmful.

The minimum point in the case of the 20 per cent. Na_2O series is not very sharply defined, but it would appear to occur in the neighbourhood of about 17 per cent. As a matter of fact, the values obtained with the glasses available fluctuate between 11·29 and 18·84 per cent. for boric oxide. This is to be expected, however, owing to the effect of variation in the amount of sodium oxide present from glass to glass. It is, unfortunately, very difficult to prepare a series of glasses in which any one constituent remains absolutely constant, and it will be noted from the table of full compositions * that the percentage of sodium oxide in the case of the 11·29 and the 18·84 per cent. boric oxide glasses is identical,

* This Journal, TRANS., 1923, **7**, 69.

but the glass containing 14·45 per cent. of boric oxide contains 1·0 per cent. more of sodium oxide than the others; and this difference amply accounts for the rise of thermal expansion.

In the case of the 10 per cent. sodium oxide series, the actual thermal expansions are very much lower than in the first series, and, moreover, the minimum thermal expansion is quite definitely marked, occurring at approximately 20 per cent. of boric oxide. As in the 20 per cent. sodium oxide series, however, the values are

Coefficient of Expansion
A. $Na_2O = 20\%$
B. $Na_2O = 10\%$

Linear Expansion × 10⁷

B_2O_3 per cent in the Glass
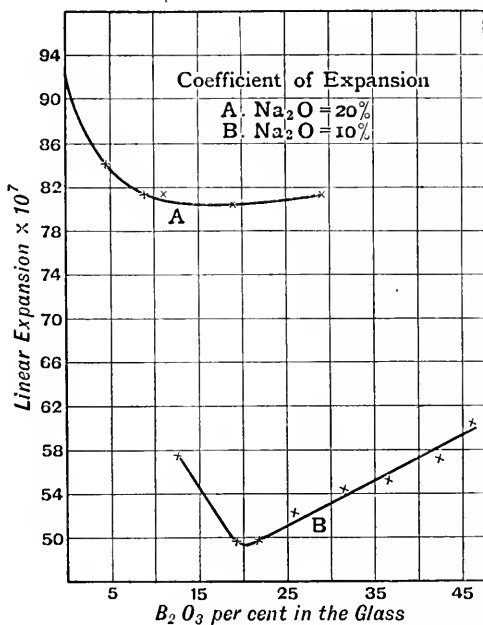
Fig. 1.

affected by variation in the actual percentage of sodium oxide present. Thus, in the first glass of the second series, 11·26 per cent. Na_2O was actually present compared with 9·79 per cent. in the second member of the series. We are bound to exercise caution in pronouncing definitely on this minimum point, especially in view also of the fact that, by extrapolation from our thermal expansion values for the sodium silicate glasses,* the value of a for a glass containing 90 per cent. of silica and 10 per cent. of soda is about 435×10^{-8}. This figure is lower than any obtained for the boric oxide glasses, even the minimum, and would mean the

* This Journal, TRANS., 1921, **5**, 121.

existence, not only of a minimum, as shown by our curve, but also of a maximum lying between 0 and 12·45 per cent. B_2O_3.

It will be seen that the calculated expansions vary from the observed. They are of a see-saw character, being affected in this respect by the slightly varying sodium oxide content. As a matter of fact, the thermal expansions of glasses rich in silica or rich in boric oxide are so small as compared with those of even small sodium oxide content that it is not easy to demonstrate the relative effects of silica and of boric oxide. A more effective way of doing this would be by preparing a series of glasses containing the two oxides only, or at least, if they contained a base, one with influence on thermal expansion very much less than sodium oxide.

It has been suggested by R. Abegg, as one way of explaining the maximum obtained on the refractive index curve when boric oxide is added to an alkali silicate, that the action of boric oxide is to displace silica. In the case of the thermal expansion, the theory seems inapplicable. For, supposing, as is most probable, that silica is partly displaced from combination, we should expect the sodium borate or whatever compound is formed to have a larger coefficient of expansion than silica and hence the expansion of the glass should be increased. Any excess of B_2O_3 would also in like manner raise the expansion if Ditte's value, previously referred to, is in any way correct. It might be argued that sodium silicate possibly has a bigger coefficient of expansion than sodium borate, and on this ground a diminution of expansion would first occur and only be followed by an increase when considerable excess of boric oxide was added. The soundness of this argument could only be tested by direct determination, and the data are not yet available. We might also expect, on this line of argument, that in a series of sodium silicate glasses a distinct diminution in the value of the expansion should occur when free silica was present, that is, when the silica was in excess of the composition $Na_2O,2SiO_2$. Our previous determinations for the sodium silicates unfortunately just start from the point at which about 66 per cent. of silica is present, so that no decision can be made on this point.

The facts which clearly emerge are that (1) on addition of boric oxide to sodium silicate, the coefficient of expansion of the glass produced is first of all reduced, ultimately reaches a minimum value, and then increases; (2) the additive relationship between thermal expansion and chemical composition shown by Winkelmann and Schott to subsist for many glasses certainly does not hold good for the boric oxide glasses over a wide range.

II. *The Densities.*

Powdered glass, crushed and sieved so as to lie between 10- and 20-mesh, was used for the purpose after being thoroughly annealed. The results of the determinations are contained in Table II.

TABLE   II.

The Density of Sodium Borosilicates at 25°.

A. *Glasses containing approximately 20 per cent.* Na_2O.

Per cent. B_2O_3.	Density. Observed.	Calcd.	Per cent. B_2O_3.	Density. Observed.	Calcd.
0·00	2·3748	2·377	18·84	2·5126	2·495
4·46	2·4291	2·425	28·83	2·4890	2·568
8·28	2·4710	2·436	39·99	2·4526	2·683
11·29	2·4919	2·454	43·70	2·4262	2·696
14·45	2·5055	2·475			

B. *Glasses containing approximately 10 per cent.* Na_2O.

12·45	2·4173	2·405	31·26	2·2672	2·502
18·71	2·3449	2·414	36·17	2·2269	2·545
21·81	2·3215	2·434	42·23	2·2020	2·574
25·82	2·2862	2·475	46·07	2·2072	2·615

The densities calculated from the linear relationship on the basis of the factors worked out by Baillie are also inserted. In the case of the density, the effect of SiO_2 and B_2O_3 is not obscured by their possessing very low factors. The deviation between the calculated and the observed values is quite obvious, the former continuously rising in both series and the observed values rising only to a maximum and then diminishing except in the last glass of the second series, namely, that containing 46·07 per cent. B_2O_3. The slight rise in this case may be due to the fact that in this glass the sodium oxide content is 11·49 per cent., slightly more than 1 per cent. greater than in the preceding glass of the same series.

Fig. 2 shows these results in graphical form.

With the 20 per cent. Na_2O series, the maximum point lies at a composition between 14·45 and 18·84 per cent. of boric oxide; that is to say, in the neighbourhood of 16 or 17 per cent., which was the maximum point on the thermal expansion curve.

With the 10 per cent. Na_2O series, the curve shows similarity to the annealing temperature curve for the same series of glasses. The point of maximum density must be reached prior to a concentration of 12·45 per cent. B_2O_3. By extrapolation from Peddle's curves for the density of the sodium silicates, the value for the glass

containing 90 per cent. SiO_2 and 10 per cent. Na_2O should be 2·273, and a maximum would probably be reached, therefore, between 10 and 12 per cent. B_2O_3.
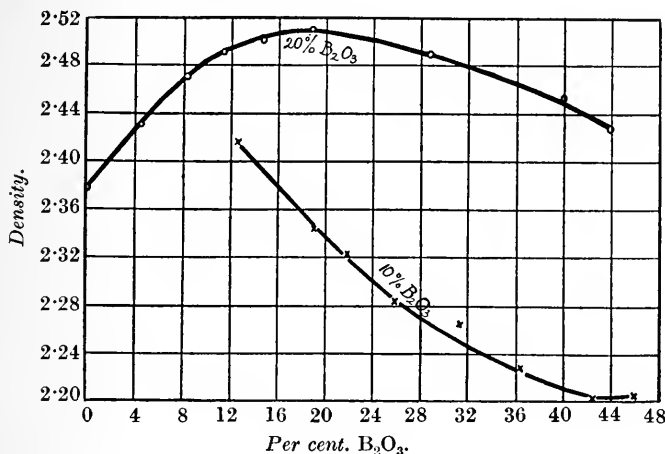
Fig. 2.

III. *The Refractive Index and Dispersion.*

These determinations were made on well polished plates of the material by the aid of the Pulfrich refractometer. The results are as follows:

TABLE III.

Refractive Indices and Dispersions.

A. *Glasses containing approximately* 20 *per cent.* Na_2O. *Dispersion.*

Per cent. B_2O_3.	μ_C.	μ_D.	μ_F.	μ_G.	F—C.	ν.	$\dfrac{n^2-1}{n^2+2} \cdot \dfrac{1}{d}$.
0·00	1·48775	1·49019	1·50267	1·51623	0·01492	32·9	0·1217
4·46	1·49868	1·50110	1·51375	1·52705	0·01507	33·8	0·1215
8·28	1·50874	1·51130	1·52372	1·53703	0·01498	34·1	0·1213
11·29	1·51361	1·51610	1·52855	1·54180	0·01494	34·5	0·1213
14·45	1·51582	1·51833	1·53058	1·54400	0·01476	35·1	0·1211
18·84	1·51881	1·52124	1·53384	1·54607	0·01503	34·8	0·1212
28·83	1·52277	1·52532	1·53746	1·55084	0·01469	35·7	0·1231
39·99	1·52023	1·52335	1·53506	1·54811	0·01483	35·4	0·1245
43·70	1·51940	1·52181	1·53421	1·54753	0·01481	35·3	0·1257

B. *Glasses containing approximately* 10 *per cent.* Na_2O.

12·45	1·50199	1·50451	1·51284	1·51654	0·01085	46·4	0·1228
18·71	1·49322	1·49542	1·50271	1·50718	0·01049	47·2	0·1244
21·81	1·49037	1·49277	1·50109	1·50422	0·01072	46·0	0·1252
25·82	1·48695	1·48924	1·49765	1·50182	0·01070	45·7	0·1262
31·26	1·48541	1·48761	1·49631	1·50086	0·01090	44·7	0·1270
36·17	1·48292	1·48558	1·49381	1·49815	0·01089	44·6	0·1288
42·23	1·48234	1·48490	1·49314	1·49758	0·01080	44·9	0·1301
46·07	1·48550	1·48790	1·49603	1·50047	0·01053	46·3	0·1304

Fig. 3 shows graphically that a maximum value of the refractive index is reached in the case of the 20 per cent. Na_2O series at about 30 per cent. boric oxide. In the 10 per cent. series, there is a continous fall, probably, however, from a maximum value attained at a composition prior to 12·45 per cent. of boric oxide. From Peddle's curves again, the refractive index for the D-line for the glass containing 90 per cent. SiO_2 and 10 per cent. Na_2O should be 1·474. A maximum must, therefore, occur, probably between
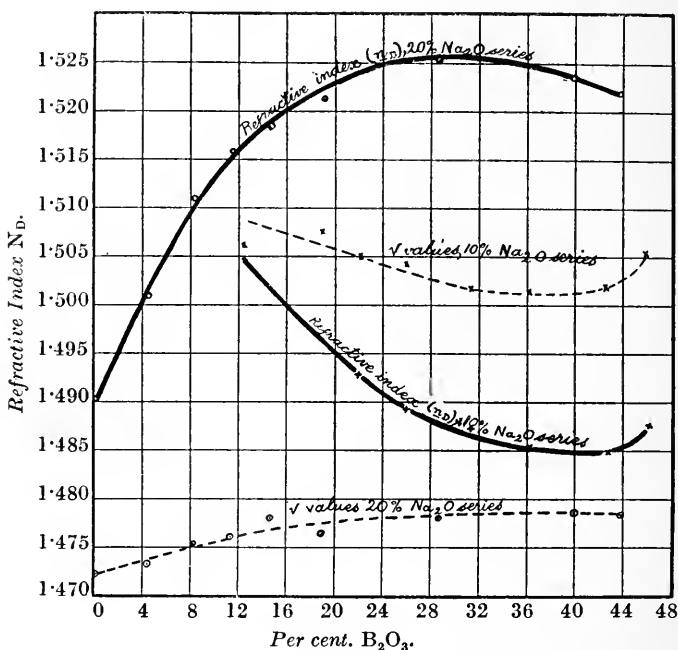
FIG. 3.

10 and 12 per cent. of B_2O_3, as in the case of the annealing temperature and the density.

It may be noted that the diminution of refractive index which occurs after a maximum is reached is not continuous in the last glass of the series, namely, that containing 46·07 per cent. B_2O_3. This is quite in keeping with the density result and is most probably due to the increase in the amount of sodium oxide present in this glass as compared with the preceding members of the series.

In regard to the values of total dispersion, it will be noted that these remain practically constant throughout each series. The actual value due to replacing 1 per cent. of silica by 1 per cent.

of boric oxide is, however, dependent on the other constituents present, and it will be noted that whereas in the first series with 20 per cent. sodium oxide the average total dispersion is 0·0149; in the series containing approximately 10 per cent. sodium oxide, the average value is 0·0107.

The values of v also remain practically constant throughout the first series, although in the second (and remembering the remarks already made as to the sodium oxide content in the last member), very slight diminution in value appears to occur as boric oxide progressively substitutes silica.

DISCUSSION OF RESULTS.

The variation with composition of the physical properties of the sodium borosilicates, as exemplified by the thermal expansion, the density, the annealing temperature, and the refractive index, is unique in character. In all glasses hitherto investigated, other than those containing boric oxide, the curve showing the relationship of the physical properties to the percentage composition by weight has been found to be, approximately, a straight line.

Thus, the curves of refractive index for all mixtures of albite and anorthite, as also for $CaSiO_3$ and $MgSiO_3$, are practically straight lines; whilst the curve for the density of the mixtures of albite and anorthite is almost a straight line and for $CaSiO_3$ and $MgSiO_3$ nearly so. On plotting the refractive index or density, in these cases, against the percentage volume composition, Tillotson * found a break in the curve for $CaSiO_3$ and $MgSiO_3$ mixtures, corresponding, he considered, with the formation of a compound. Nevertheless, each portion of the curve was a straight line and showed no maximum or minimum.

In our various investigations on the physical properties of tri-silicate glasses, that is, of the type $6SiO_2, xNa_2O, yCaO$ where $x + y = 2$, the thermal expansions, density, and refractive index curves have not departed greatly from the straight line over the composition investigated and in the case of the annealing temperature only have we discovered a minimum, namely, in the case of the soda–lime–magnesia silicate glasses. The variation of annealing temperature, however, has never been found to be nearly a straight line.

Further, Peddle's researches showed that for the glasses of the various series

$$100SiO_2, 20Na_2O \text{ to } 100SiO_2, 100Na_2O\;;$$
$$100SiO_2, 40Na_2O, 5CaO \text{ to } 100SiO_2, 40Na_2O, 40CaO\;;$$
$$100SiO_2, 20Na_2O, 5CaO \text{ to } 100SiO_2, 20Na_2O, 40CaO\;;$$

* E. W. Tillotson, *J. Amer. Cer. Soc.*, 1918, **1**, 76.

and the similar potash glasses, the soda–lead oxide and the potash–lead oxide glasses, the refractive index curves and the density curves did not depart greatly from the straight line.

With these numerous results before us, and the many results of the Jena school of workers, we have got accustomed to the idea of the linear relationship between physical properties and chemical composition.

In theory, it is not easy to understand why such linear relationship should subsist, over so very considerable a range, if the oxides are present in combination. The existence of linear relationships in the case of mixtures such as albite and anorthite mixtures or mixtures of $CaSiO_3$ and $MgSiO_3$ might be expected, just as linear relationships are found in a number of properties in the case of metals or of compounds mutually soluble in all proportions. It should not follow, however, that in a series like $6SiO_2,xNa_2O,yCaO$ the replacement of soda by lime should give a linearly varying property; or in the case where lime is added to the glass $100SiO_2,40Na_2O,xCaO$. There is good evidence to show that the disilicate $Na_2O,2SiO_2$ is the form prevailing in many glasses, whilst the monosilicate, $CaSiO_3$, appears to be produced in the case of lime, unless the latter be in very considerable concentration. Assuming these compounds to be present in soda–lime glasses, it will be seen that in the series examined by Peddle, in which the basic constituents of the glass were progressively increased, the free SiO_2 should be gradually diminished; whilst in the series examined by ourselves, replacement of Na_2O by CaO should tend to increase the amount of the free silica. Yet the same type of relationship between physical property and composition holds.

The composition of the boric oxide glasses now under study follows rather different lines from the trisilicate series previously studied by us. In each series, the sodium oxide is approximately constant and the increasing amounts of B_2O_3 added mean that both SiO_2 and B_2O_3 come into competition for the base, which is inadequate in amount to produce both sodium borate and sodium silicate. Glasses in which the bases are in excess and therefore in competition for the acid have not, so far as we are aware, been made and studied. Hence, perhaps, the uniqueness of the phenomenon now disclosed.

When boric oxide is added to sodium silicate, the base, sodium oxide, being insufficient to saturate both the SiO_2 and the B_2O_3, one of two main reactions may occur. In the first place, sodium borate, probably $NaBO_2$ (especially for small additions of B_2O_3), is formed, so that we may have $NaBO_2$, sodium silicate ($Na_2O,2SiO_2$), and excess of SiO_2 all present.

Now if the refractive index of $NaBO_2$ exceeds that of B_2O_3, SiO_2, or the silicates, the addition of boric oxide in the manner indicated above should result in producing a mixture or glass with increasing refractive index, and ultimately a maximum value must be reached, so long as the basic oxide is insufficient for both the boric and silicic oxides.

Actually, the refractive index values for the D-line are : fused boric oxide 1·462 *; fused silica 1·45847 †; all sodium silicates lying between 100 molecules SiO_2, 20 molecules Na_2O, and 100 molecules SiO_2, 100 molecules Na_2O ‡ between 1·485 and 1·517. The maximum value obtained in the borosilicates with 20 per cent. Na_2O slightly exceeds 1·525. If the course of the reaction is as above outlined, sodium borate, $NaBO_2$, should have a refractive index appreciably higher than 1·525. A test of this point would be helpful.

Since the equilibrium between the oxides should vary with their relative amounts, the maximum or minimum point should be displaced as the amount of the alkaline oxide varies. For in the two series considered, the ratio of SiO_2 to B_2O_3 is different, for any percentage of B_2O_3, according as 20 or 10 per cent. Na_2O is present. If it be that the main increase in refractive index is due to formation of Na_2BO_2, then in the 10 per cent. Na_2O series, the formation of this compound ought to be delayed as compared with the 20 per cent. Na_2O series; in other words, the maximum point might be expected to occur at a higher B_2O_3 percentage. Instead, it appears to take place with a smaller percentage addition of B_2O_3 than in the 20 per cent. series.

Abegg's theory § that the maximum refractive index found by Zschimmer when 15 parts of B_2O_3 were added to an alkaline silicate was to be explained as due to the setting free of more and more silica, has also been suggested as explaining why additions of B_2O_3 to the same type of glass increases the durability to a maximum and subsequently decreases it. Assuming such a theory to have any real value, we are led to surmise what may be the cause of the increase of durability in the trisilicate soda–lime glasses when CaO replaces Na_2O. As already stated, replacement of Na_2O by CaO should lead to the liberation of silica in the glass, assuming the compounds concerned to be $Na_2O,2SiO_2$ and $CaSiO_3$, respectively. We do know that increasing the concentration of CaO increases the durability. On Abegg's theory, it would be arguable that this

 * E. Zschimmer, *loc. cit.*
 † J. W. Gifford and W. A. Shenstone, *Proc. Roy. Soc.*, 1904, **73**, 201.
 ‡ C. J. Peddle, this Journal, TRANS., 1920, **4**, 12.
 § Abegg's " Handbuch der anorg. Chem," 1906, III, **1**, 26.

improvement is not due to the calcium silicate, but to the increase in the proportion of free silica. We have no evidence that this reason is valid. Certainly we could gain some information as to the real effect of adding lime by starting with the glass $Na_2O,2SiO_2$ and determining the effect on its properties of adding $CaSiO_3$, and perhaps comparing the effect with that of adding CaO. We propose to carry out such tests.

Turning to a comparison of the maxima or minima obtained in different properties, there appears at first sight to be a further anomaly, for the maxima or minima are found to occur at the following percentages of boric oxide :

	20 per cent. Na_2O series.	10 per cent. Na_2O series.
Annealing temperature	16—17	10—12
Thermal expansion	16—17	20
Density	16—17	10—12
Refractive index	30	10—12

We should expect, for each series, the same maximum or minimum for all properties. In practically all cases this concordance exists. There are anomalies, however, in the case of the thermal expansion of the 10 per cent. Na_2O series and the refractive index of the 20 per cent. Na_2O glasses.

In regard to the thermal expansion, we have already pointed out how considerably the value is affected if the percentage of the Na_2O present does not remain quite constant. Actually, the amount of sodium oxide does vary distinctly so that precise comparison of the different glasses becomes rather difficult to make in such circumstances.

The anomaly with the refractive index largely disappears if, as in Fig. 4, we plot the specific refraction against the percentage composition. We then get a sharp break in the curve at about 12 per cent. B_2O_3 in the 10 per cent. Na_2O series and at about 18—19 per cent. in the 20 per cent. Na_2O series. The two portions of the curves in each case are approximately straight lines.

Finally, we may consider whether or not the striking variation in the physical properties described are to be associated with the formation of new types of compounds. Theories have been propounded, indeed, that both alumina and boric oxide form complex acids with silica and the terms aluminosilicate and borosilicate are commonly applied. We have failed to discover any real evidence, however, of the existence of aluminosilicates and certainly the soda–alumina–trisilicate glasses and the soda–lime–alumina–trisilicate glasses we have studied do not show any evidence of abnormal behaviour different, for example, from the soda–lime

trisilicates or the soda–magnesia–trisilicates. The theory that the increase in durability of glasses due to the addition of boric oxide is due to the formation of borosilicates is still waiting for real evidence of its validity. Possibly the specific refraction curves might furnish an indication, if we assume, with Tillotson, that breaks in property–composition curves of glasses may be explained on the basis of compound formation.
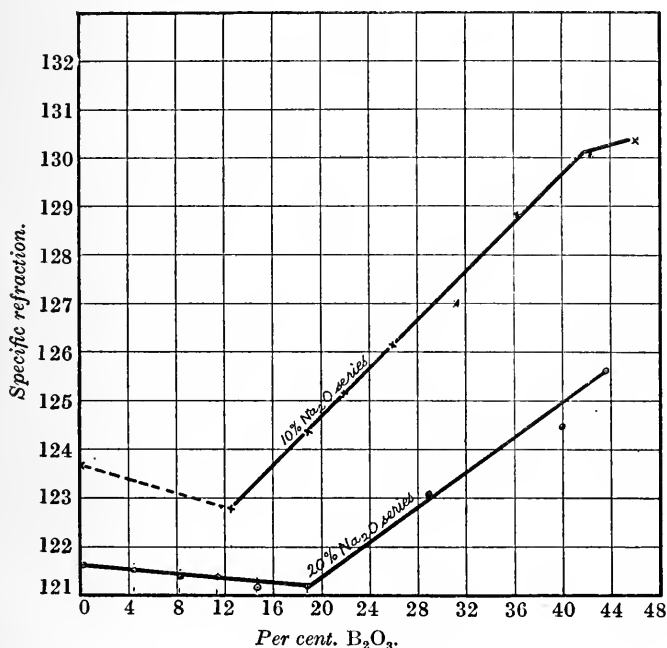
FIG. 4.

The break in the specific refraction curve for the 20 per cent. Na_2O series occurs when the amount of B_2O_3 present is about 18—19 per cent. If the figure be assumed as 18·5 per cent., then the percentage composition of the mixture at the break will be SiO_2 61·5, Na_2O 20, B_2O_3 18·5, or, molecularly, 1·025 : 0·323 : 0·313, that is, approximately, 3 : 1 : 1. Whether or not this ratio has any special significance calls for further test; but it is conceivable that a compound is formed by the displacement of SiO_2 in $Na_2O, 2SiO_2$ by B_2O_3, yielding Na_2O,B_2O,SiO_2, there being $2SiO_2$ in excess at this stage. We would note that in the 10 per cent. Na_2O series, the maximum or minimum probably occurs when the B_2O_3 content is somewhere in the region of 10—12 per cent. If we assume

11 per cent., then the oxide percentages are SiO_2 79, Na_2O 10, B_2O_3 11; if it be 10 per cent. we have SiO_2 80, Na_2O 10, B_2O_3 10. In any case, it is clear that the molecular proportions of Na_2O and B_2O_3 are again in the region of 1 : 1. If the break indicated compound formation, it certainly does not seem to mean that it corresponds precisely in composition with a compound Na_2O,B_2O_3,SiO_2. It could only mean that such a compound reached its maximum concentration at this point.

A difficulty of interpretation arises, however, in connection with the properties other than specific refraction. Neither the percentage composition–density curves nor the percentage composition–specific volume curves show any break; nor when the thermal expansion is plotted against the percentage weight or volume composition. Moreover, if the compound Na_2O,B_2O_3,SiO_2 be formed; and if, further, the durability of borosilicates be associated with the formation of such a compound, we should expect maximum durability when the amount of this compound formed was at the maximum. In other words, the maximum durability should occur at much the same point as the break in the specific refraction curve. Investigations carried out in this laboratory * on the 20 per cent. Na_2O series show that the maximum durability occurs when between 11 and 14 per cent. of B_2O_3 is present, a different value from those for the other properties.

Clearly the results we have obtained raise a large number of interesting speculations and open the way for considerable further investigations.

Summary.

(1) Measurements have been made of the thermal expansion, the density, refractive index and dispersion of two series of sodium borosilicates, the first series containing approximately 20 per cent. of sodium oxide, the second 10 per cent. In each case, the silica present was progressively substituted by boric oxide until in the 20 per cent. Na_2O series as much as 43·7 per cent. B_2O_3 was present and in the second series 46·07 per cent.

(2) It was shown that the linear relationships between chemical composition and physical properties which had been found to subsist over a considerable range for many types of glasses do not hold in the case of the sodium borosilicate glasses. Minima occur in the thermal expansion curves and maxima in the case of the density and refractive index as also in the case of the annealing temperature.

* See *J. Roy. Soc. Arts*, 1923, **71**, 401.

(3) Winkelmann and Schott's thermal expansion factors clearly do not hold for the boric oxide glasses, except over a very limited range.   The density factors, whether those of Winkelmann or those of Baillie, likewise are inapplicable to the boric oxide glasses, except for comparatively small concentrations of that oxide.

(4) On practical grounds, the value of boric oxide for the preparation of glasses of low thermal expansion is limited, since beyond a certain amount the expansion increases instead of decreases.

(5) Various theories are discussed to explain the special results obtained in the case of the boric oxide glasses.

We should like to take this opportunity of expressing our thanks to Messrs. Borax Consolidated, Ltd., London, for supplies of boric acid used in the preparation of these glasses.

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XVI.—*Notes on Burettes.*

By VERNEY STOTT, B.A., F.Inst.P.

(Read at the London Meeting, May 16th, 1923.)

Graduations.

BURETTES submitted for test at the Bureau of Standards, the Reichsanstalt and for the National Physical Laboratory Class A tests must be graduated as shown in Fig. 1.   Every tenth line is carried completely round the burette and numbered.   The shortest graduation marks extend half-way round the tube, and the lines midway between the numbered marks are intermediate in length. The stop-cock should be sealed to the burette in such a position that when the burette is placed in a stand with the tap in the usual position (that is, so that it is operated by the right hand) the ends of the shortest graduation marks lie on a line running centrally down the front of the burette.   The graduation marks and numbers then appear as shown in Fig. 1 when the burette is viewed from the front.

This method of graduating burettes, however, has frequently been criticised, and it is therefore desirable to consider the matter in detail.

When reading a burette an observer should perform three distinct operations, namely : (1) Bring his eye exactly to the level of the

liquid surface. (2) Note the reading. (3) Assure himself that his eye is still at the correct level.

With burettes graduated as previously described, the above operations can be carried out with extreme ease and errors due to parallax avoided. By placing his eye so that the front and back portions of the line nearest to the liquid surface are seen to coincide, the observer at once brings his line of vision into the correct position. The reading is then noted and a final glance at the graduation mark suffices to ensure that the eye is still at the correct level.

A very large number, probably the majority, of the burettes manufactured, however, are not graduated in the above manner, but simply have short graduation marks down the front of the tube. Every fifth and tenth line is somewhat longer than the rest, but with none of the graduation marks is it possible to eliminate errors due to parallax in the manner described above.

Numerous devices, for example, floats, attachable mirrors, reading telescopes, burettes with enamelled backs, and burettes with silvered backs, have been proposed from time to time for use with burettes graduated with short lines only. The object of the devices is to obtain increased accuracy of reading, and many of them aim at, and some are erroneously supposed to achieve, the elimination of errors due to parallax. The mere existence of the devices is an admission of the unsatisfactory nature of short line graduations for accurate readings.

There is one objection to the method of graduations shown in Fig. 1, which on the face of it appears to carry some weight. It is urged that the length of the lines gives the burette a confused appearance, which is trying to the eyes. This is no doubt true if one glances casually at such a burette, but if, as is the case when the burette is in use, one's attention is concentrated on the graduation marks in the immediate neighbourhood of the liquid surface, no sense of confusion arises, in fact quite the reverse. The fact of being able to bring the front and back portions of the line nearest the liquid surface into coincidence, creates a sense of certainty rather than of confusion.

FIG. 1.

Method of Reading Burettes.

In the case of transparent liquids the convention of reading the position on the scale of the lowest point of the meniscus is practically universal.

The following extremely simple device is very effective in showing up the outline of the meniscus. A strip of opaque black paper, such as is used for wrapping photographic plates in, is folded round the glass tube just below the meniscus as shown in Fig. 1. The top edge of the strip is cut clean and straight and should be placed not more than 1 mm. below the bottom point of the meniscus. The paper should be so folded that the top edges of the two ends of the strip, where they meet after encircling the tube, are exactly
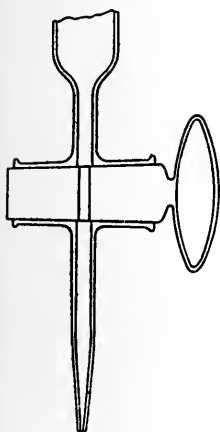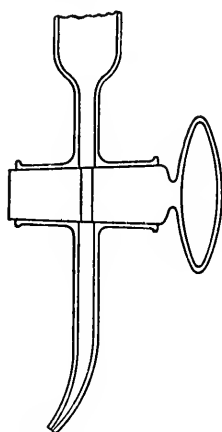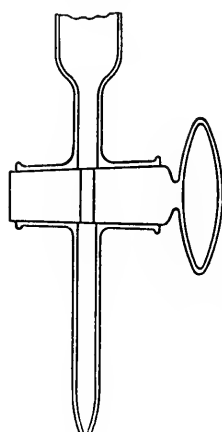
FIG. 2.   FIG. 3.   FIG. 4.

in line. The strip is held in position by means of a detachable paper clip. If the meniscus so shaded is viewed against a white background, the bottom of the meniscus appears quite black, and its outline is very sharply defined against the white background.

Jets and Stopcocks of Burettes.

In order that liquid may be delivered from a burette sufficiently slowly it is necessary for the diameter of the orifice of the jet to be quite small. The jets may, however, be made comparatively strong by making the jet with thick walls so that the external diameter at the end of the jet is from 2 mm. to 3 mm. The jets should be made with a gradual internal taper as shown in Fig. 2. The end of the jet should be ground off square and the ground surface should be smooth, preferably polished. It is an advantage

N 2

to bevel the jet slightly and so remove any chips which develop in grinding the end of the jet.

The Bureau of Standards, Washington, recommend that burette jets should be made curved as shown in Fig. 3 in order to avoid splashing. Many chemists, however, prefer a straight jet which delivers directly into the liquid in the receiving vessel. Most burettes manufactured in this country have straight jets.

Burette jets which taper rapidly (see Fig. 4) or have a sudden constriction at the orifice, caused by reducing the size of the opening by heating the end of the jet in a flame after cutting off the drawn-out portion, are objectionable. They are more likely to cause splashing than a jet with a gradual taper, and a slight damage to the end of the jet may alter the delivery time very considerably. The jets are also difficult to clean if any dirt lodges on the shoulder just inside the orifice.

Some chemists * prefer to use jets which have a much smaller external diameter than that given above, and terminate in a fairly long cylindrical portion not more than 1 mm. in external diameter. This is in order to obtain small drops when liquid is being run from the burette a drop at a time. Such jets are manifestly fragile and probably a thick-walled jet with a fine orifice, as previously described (Fig. 2), would be much more generally preferred. Further, there is no necessity to take a whole drop at a time from a thick-walled jet. A fraction of a drop may be detached on to the inside of the receiving vessel and washed down with water into the main body of the liquid.

Attention might perhaps usefully be directed to the following statement : " Tap burettes are frequently provided with an inconvenient and undesigned air trap under the barrel of the tap." †
The internal diameter of the tubing from which the jet is made should be approximately equal to the diameter of the hole drilled through the key of the tap. Also in sealing the jet to the barrel of the tap the internal diameter of the jet should not be enlarged appreciably. If the internal diameter of the jet is much larger than the diameter of the hole through the key, then the jet is liable not to become completely filled with liquid when the burette is in use.

Filling Tubes of Burettes.

Burettes are sometimes made with a glass side tube sealed to the burette between the lowest graduation mark and the tap.

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* See, for example, " Note on Jets for Burettes," by J. H. Coste. *The Analyst,* December, 1917.

† J. H. Coste, *loc. cit.*

This is not satisfactory. In use, the side tube is attached to a stock bottle by means of indiarubber tubing, and any expansion or contraction of the indiarubber tubing hence causes an error in the burette reading. If a filling tube is necessary, burettes with a two-way tap should be used.

Leakage of Burette Taps.

The key of a burette tap should be ground into the barrel so that the two are a good fit. Leakage should be prevented by the goodness of the fit of the key in the barrel and not by the liberal application of grease.

Burettes submitted to the National Physical Laboratory for test are tested for leakage as follows. The key is removed from the barrel and both key and barrel are thoroughly cleaned to remove all traces of grease. The key is then dipped in water and replaced in the barrel of the tap. The burette is then placed vertical in a stand and filled with water, the water surface being accurately set on the 0 c.c. mark. The burette is left for about half an hour or longer with the tap in one shut-off position. The position of the water surface is read several times during the above period and notes made of the time which elapses between setting the water surface on the 0 c.c. mark and taking the subsequent readings. The above procedure is repeated with the key in the second shut-off position.

If the rate of leakage under the above conditions exceeds 0·1 mm. change in the position of the water surface per minute, the burette is rejected and the capacity test is not carried out.

Burettes which pass the above test are found to be quite satisfactory when used with quite a small quantity of grease on the tap. A rubber and paraffin tap lubricant is used, a small spot of the lubricant being placed at each end of the key and spread out into a thin film by repeatedly turning the key in the barrel.

It was found impossible to test burette taps satisfactorily for leakage if grease was used on the tap. Quite bad taps can be made to withstand leakage for an appreciable time if they are sufficiently greased and the tap is not turned throughout the period during which leakage is tested. Such taps, of course, fail in actual use when they are repeatedly turned on and off.

Rate of Outflow and Drainage of Burettes.

The quantity of water delivered from a burette varies with the rate at which the burette is emptied. Again, owing to the drainage of liquid down the walls of the burette, the reading

obtained varies according to the time which elapses between closing the tap and taking the reading. Variations in the rate of outflow and in the drainage time give rise to errors which are much larger than is usually realised.

Schlœsser carried out some investigations on the question,* and valuable results were obtained also by Osborne and Veazey.† The latter observed the rise of the water surface in a burette tube after a definite length had been emptied, observations being taken for different rates of outflow, for various lengths of tube and for tubes of different diameters. Their conclusions may be gathered from the following extract.‡

" By limiting the rate of outflow the residue and the afterflow may be made negligibly small. The system of curves considered with reference to the rate of outflow enables a choice of outflow rate which shall sufficiently limit the afterflow. For the maximum or initial rate of outflow a value was sought which should render the residue and drainage so small that the volume delivered should be independent of such variations in manipulations as are often found necessary by the chemist. Reference to the curves shows that for an initial rate of 0·7 cm. per second the maximum drainage from any interval emptied which occurs during the first two minutes after stopping outflow is about 0·05 mm.§ This initial rate was selected, and the specifications in regard to time of outflow of the total graduated length were so chosen, that on burettes of customary proportions the maximum initial rate should not exceed 0·7 cm./sec."

The times specified are given below.‖ " For any graduated interval the time of free outflow must not be more than three minutes, nor less than the following for the respective lengths : "

TABLE I.

Length graduated (cm.)	15	20	25	30	35	40	45	50	55	60	65	70
Time of outflow not less than (sec.)	30	35	40	50	60	70	80	90	105	120	140	160

The results obtained by the Bureau of Standards were taken into account in preparing the National Physical Laboratory ¶ specifications given below :

* *Zeitsch. angew. Chem.*, 1903, **16**, 953 and *Chemiker-Zeitung*, 1904, **33**, 4.
† *Bull. Bureau of Standards*, 1908.
‡ *Loc. cit.*, p. 584.
§ That is a rise of 0·05 mm. in the water surface.
‖ Circular of the *Bureau of Standards*, 1916, No. 9, p. 17.
¶ Test Pamphlet, " Volumetric Tests on Scientific Glassware," November, 1919, issued by the National Physical Laboratory.

TABLE II.

Length graduated (cm.)		15	20	25	30	35	40	45	50	55	60	65	70	75
Class A Burettes	Minimum time of outflow (sec.)	30	40	50	60	70	80	90	100	110	120	130	140	150
	Maximum time of outflow (sec.)	60	80	100	120	140	160	180	200	220	240	260	280	300
Class B Burettes.	Minimum time of outflow (sec.)	20	30	35	45	50	55	60	70	75	80	85	90	100
	Maximum time of outflow (sec.)	60	80	100	120	140	160	180	200	220	240	260	280	300

It will be seen that the minimum times for Class A burettes are in close agreement with the corresponding Bureau of Standards times. Instead, however, of specifying a maximum time of three minutes applicable to all lengths, the maximum time was in each case fixed as twice the minimum time. The minimum times for Class B burettes were made smaller than for Class A burettes, because the former are not expected to be used for work requiring the highest degree of accuracy.

Although the work of the Bureau of Standards enabled delivery time to be specified on a sound basis, it was thought desirable to carry out a more detailed investigation on a 50 c.c. burette, the most commonly used size, in order to be in a position to study in detail its behaviour under various conditions. The following investigation was therefore carried out on a 50 c.c. burette of internal diameter approximately 11 mm. The length occupied by the graduated scale, that is, the distance from the 0 c.c. mark to the 50 c.c. mark was 534 mm. The burette was of the type for use with a jet attached by means of indiarubber tubing. A series of seven jets was prepared which gave the following delivery times in seconds : 206, 152, 106, 74, 56, 37, and 20.

By " delivery time " is meant the time occupied by the un-restricted outflow of water from the zero mark to the lowest gradu-ation mark, for example, for a 50 c.c. burette fitted with a stopcock the delivery time of the burette is the time taken to empty it from the 0 c.c. mark to the 50 c.c. mark, using water and keeping the stopcock fully open. The above meaning is to be understood whenever the delivery time of a burette is referred to.

With each jet in turn the following observations were made. The burette was mounted in front of a reading telescope provided

FIG. 5.

FIG. 6.

NOTE:—
(1) THE TIME REQUIRED TO EMPTY THE BURETTE FROM THE 0cc MARK TO THE 50cc MARK WITH UNRESTRICTED OUTFLOW IS EQUAL TO THE DELIVERY TIME OF THE BURETTE
(2) VALUES DEDUCED FROM MICROMETER READINGS MARKED ⊙
VALUES DIRECTLY DETERMINED BY WEIGHING MARKED ✕

DELIVERY TIME OF BURETTE. (SECONDS)

VOLUME OF WATER DELIVERED FROM 0cc MARK TO 50cc MARK WITH UNRESTRICTED FLOW
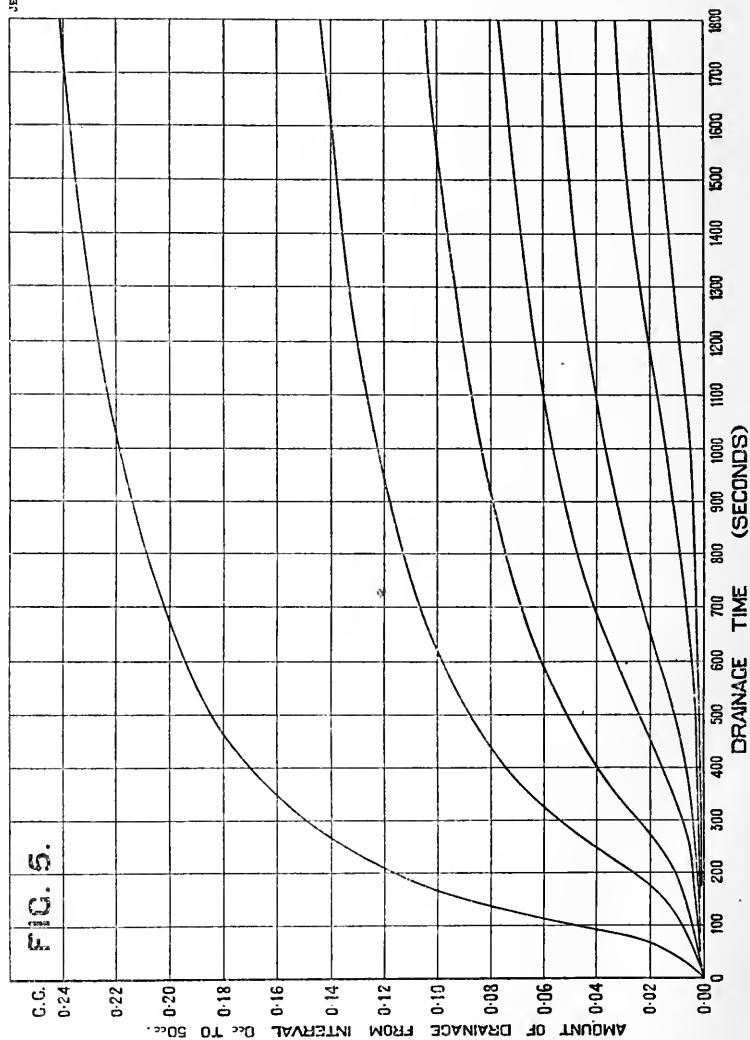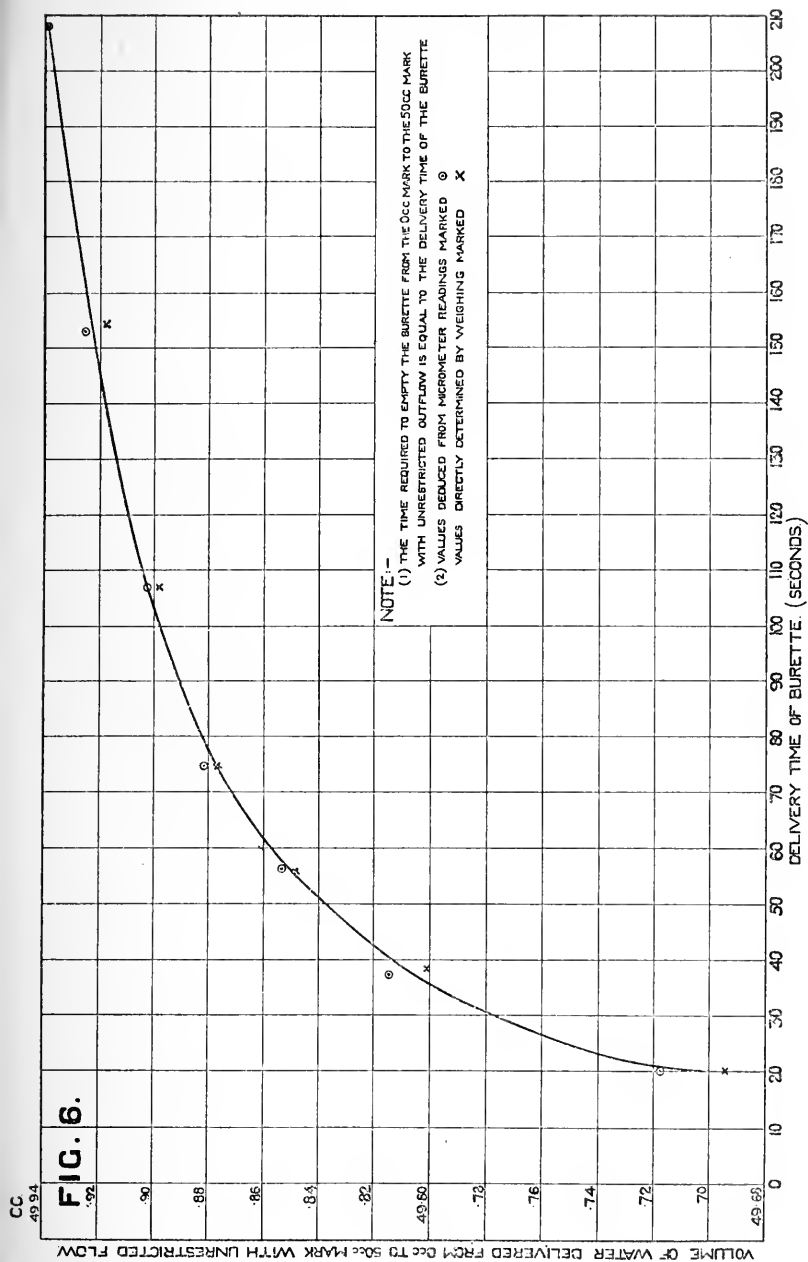
with a micrometer eyepiece and a movable horizontal crosswire, and was filled from below with distilled water to a few millimetres above the 0 c.c. mark. Water was run out from the burette very slowly until the bottom of the meniscus was exactly on the 0 c.c. mark. The burette was allowed to empty freely until the water surface was between the 49·9 c.c. mark and the 50 c.c. mark, and the time of outflow noted. The moving horizontal cross-wire of the telescope was set on the bottom of the water meniscus as soon as possible after the outflow was stopped, in general within five to ten seconds. The reading of the micrometer scale was noted. Settings of the cross-wire on the meniscus and corresponding micrometer readings were taken at frequent intervals over a period of about half an hour.

A rise of the meniscus equivalent to 1/10 c.c. drainage corresponded to approximately 650 divisions on the micrometer scale. Settings could be repeated within a few divisions so that very small changes in the position of the meniscus could be accurately observed.

The meniscus was shaded by means of a piece of black paper as described on p. 171. It was found that with this arrangement the measured rise of the meniscus was slightly in excess of the true rise, this effect being due to the increase in the distance between the bottom of the meniscus and the edge of the black paper during the drainage time. The effect was very small, amounting only to about 0·01 c.c. for the greatest amount of drainage, namely, 0·24 c.c. observed. Appropriate corrections were applied to all the measurements made.

The results of the observations on the rise in the meniscus are given in Fig. 5. The amount of water which drained from the walls of the burette is plotted vertically, and the drainage time horizontally. The drainage time is reckoned from the time at which outflow ceased. The delivery times given by the jets used for each set of observations are shown against the curves to which they relate, and these times are equal to the times occupied in emptying the burette from the 0 c.c. mark to the 50 c.c. mark before commencing the observations on the drainage.

The curves given are smooth lines drawn through the plotted observations. Because of the large number of observations, 519 in all, the actual observations are not marked on the figure. The following table, however, gives an idea of the accuracy of the curves :

TABLE III.

Delivery time.	Number of sets of observations.	Total number of observations.	Greatest departure from mean curve.	Greatest departure from mean curve at end of 5 mins.
20 sec.	3	150	0·008 c.c.	0·004 c.c.
37	3	115	0·006	0·005
56	2	76	0·005	0·002
74	2	61	0·003	0·000₅
106	2	41	0·005	0·001
152	2	43	0·003	0·000
206	2	33	0·002	0·000₅

The values given in the last column but one of the above table represent the greatest difference between an actual observation and the corresponding point on the mean curve. For almost every mean curve the greatest departures of the observations from the mean curve occurred at the extreme right of the curves, that is, after about thirty minutes' drainage.

The values in the last column represent the greatest departure of the observational curves from the mean curves at the ordinate corresponding with five minutes' drainage. These values are considerably less than those in the preceding column. This is because the lines joining the actual observations in a given set formed a fairly smooth curve, and the curves for the independent sets for any particular delivery time agreed closely over their initial portions and diverged somewhat towards the end of the drainage time.

The following are the main facts relating to drainage which may be noted in Fig. 5.

(1) Drainage persists for a considerable time. Even at the end of half an hour the curves are still slightly inclined to the horizontal.

(2) When the rate of outflow is quick, the amount of water which drains from the walls of the burette is very large in comparison with the degree of accuracy required on a burette. The National Physical Laboratory Class A tolerance on a 50 c.c. burette is $\pm$ 0·04 c.c. When the time of outflow was twenty seconds, a volume of 0·24 c.c. drained down in half an hour, and even in the first two minutes the amount of drainage was 0·07 c.c., that is, almost twice the Class A tolerance.

(3) The total amount of drainage and the rate of drainage are very noticeably decreased by decreasing the rate of outflow. When the interval 0 c.c. to 50 c.c. was emptied in 206 seconds, the subsequent drainage amounted to less than 0·02 c.c. in half an hour, as compared with 0·24 c.c. drainage in the same time after emptying the burette in 20 seconds. The amount of water which drained

down in the second minute of the drainage period was 0·05 c.c.
when the interval 0 c.c. to 50 c.c. was emptied in 20 seconds, only
0·002 c.c. when it was emptied in 74 seconds, and less than 0·001 c.c.
when it was emptied in 206 seconds.

(4) The meniscus rises more slowly at the beginning of the
drainage period than it does after draining has been going on for
one or two minutes.

An interesting deduction capable of experimental verification
may be drawn from Fig. 5.

All the curves are practically parallel at the extreme right of
Fig. 5. We may interpret this as meaning that at the end of
half an hour the same amount of water is left on the walls, irrespec-
tive of the rate at which the burette was initially emptied. Hence,
the difference between the ordinates of any two curves after, say,
thirty minutes' drainage, may be taken as representing the differ-
ence in the amount of water initially left on the walls at the
beginning of the drainage period for the two curves in question.
Thus, for example, the difference in the ordinates of the curves,
marked 20 secs. and 206 secs, respectively, after thirty minutes'
drainage is $0·22_1$ c.c. Hence, when the burette is emptied from
the 0 c.c. mark to the 50 c.c. mark in 20 seconds, $0·22_1$ c.c. more
water are left adhering to the walls than when it is emptied in 206
seconds. Obviously, therefore, when the burette is emptied from
the 0 c.c. mark to the 50 c.c. mark in 20 seconds, $0·22_1$ c.c. less
water will be delivered from the burette than when it is emptied
in 206 seconds. If then we know the volume of water delivered
by the burette in 206 seconds, we can say that $0·22_1$ c.c. less would
be delivered in 20 seconds, and similarly, volumes which would
be delivered for times of outflow equal to each of the delivery
times represented in Fig. 5 can be deduced.

The quantity of water delivered by the burette when emptied
from the 0 c.c. mark to the 50 c.c. mark in 206 seconds was deter-
mined by weighing the water delivered, and was found to be
$49·93_8$ c.c. Taking this value as starting point and subtracting
from it the difference between the ordinate of the lowest curve
in Fig. 2 at 1,800 seconds, and the ordinate of each of the other
curves in turn, a series of values was obtained which are repre-
sented by the small circles in Fig. 6. On the basis of the foregoing
argument, these points represent the volume of water delivered
by the burette when emptied from the 0 c.c. mark to the 50 c.c.
mark in times equal to the various delivery times. These volumes
were independently determined by weighing the quantity of water
delivered by the burette for various times of outflow. The results
obtained are shown by crosses in Fig. 6.

It will be seen that both the crosses and the circles lie near to

the curve drawn through them in Fig. 6, and the close agreement
between the results deduced from micrometer observations and
the results obtained directly by weighing is an interesting check
on the accuracy of the observations.

By studying Figs. 5 and 6 in conjunction, very clear ideas may
be obtained of the behaviour of the burette under various conditions.
The data obtainable from the figures also serve to determine
whether the delivery times specified for standard burettes are
satisfactory. Details are given below of the results obtained with
burettes having short delivery times, and also with various standard
burettes, under different conditions.

(1) *Burettes with Short Delivery Time.*—Assume that the burette
delivered exactly 50 c.c. when emptied from the 0 c.c. mark to
the 50 c.c. mark in 20 seconds. We can determine from Figs. 5
and 6 the error which would result if the burette were emptied
in, say, 56 seconds and the reading taken two minutes after outflow
had ceased. From Fig. 6 it is seen that the burette delivered
$49\cdot70_2$ c.c. in 20 seconds and $49\cdot85_2$ c.c. in 56 seconds, and hence
$0\cdot15_0$ c.c. less water is delivered in 20 seconds than in 56 seconds.
Therefore, since we have assumed the burette to deliver exactly
50 c.c. in 20 seconds, it would deliver $50\cdot15_0$ c.c. in 56 seconds.
We have assumed the reading to be taken two minutes after the
water meniscus was stopped on the 50 c.c. mark. In this time the
curve for 56 seconds outflow time in Fig. 5 shows that $0\cdot00_5$ c.c.
of water would drain from the walls, and the reading at the end of
two minutes' draining would therefore be $49\cdot99_5$ c.c. We have seen
that the volume delivered would be $50\cdot15_0$ c.c., so that the burette
reading would be $0\cdot15_5$ c.c. less than the volume actually delivered.

The following table has been prepared in the above manner
from Figs. 5 and 6, and gives a few examples of the results which
would be obtained for the interval 0 c.c. to 50 c.c. under various
conditions.

TABLE IV.

Conditions of Use.			Volume of water delivered.	Burette reading.	
Duration of outflow.	Drainage time.	Total time.	V c.c.	R c.c.	$(V - R)$ c.c.
20 sec.	0 sec.	20 sec.	$50\cdot00_0$	$50\cdot00_0$	$0\cdot00_0$
,, ,,	40 ,,	1 min.	$50\cdot00_0$	$49\cdot99_1$	$+ 0\cdot00_9$
,, ,,	100 ,,	2 ,,	$50\cdot00_0$	$49\cdot95_0$	$+ 0\cdot05_0$
,, ,,	280 ,,	5 ,,	$50\cdot00_0$	$49\cdot85_5$	$+ 0\cdot14_5$
56 ,,	4 ,,	1 ,,	$50\cdot15_0$	$50\cdot00_0$	$+ 0\cdot15_0$
,, ,,	64 ,,	2 ,,	$50\cdot15_0$	$49\cdot99_8$	$+ 0\cdot15_2$
,, ,,	244 ,,	5 ,,	$50\cdot15_0$	$49\cdot98_4$	$+ 0\cdot16_6$
106 ,,	14 ,,	2 ,,	$50\cdot20_0$	$50\cdot00_0$	$+ 0\cdot20_0$
,, ,,	194 ,,	5 ,,	$50\cdot20_0$	$49\cdot99_8$	$+ 0\cdot20_2$
206 ,,	94 ,,	5 ,,	$50\cdot23_8$	$50\cdot00_0$	$+ 0\cdot23_6$
,, ,,	394 ,,	10 ,,	$50\cdot23_6$	$49\cdot99_9$	$+ 0\cdot23_7$

(2) *Burettes with short Delivery Time calibrated for 3 min. Drainage Time.*—Suppose the burette to be calibrated so that the volume of water delivered from the 0 c.c. mark to the 50 c.c. mark in 20 seconds agrees with the burette reading taken after allowing three minutes' drainage. The results which would be obtained for the interval 0 c.c. to 50 c.c. with such a burette under various conditions are given below.

TABLE V.

Conditions of Use.			Volume of water delivered.	Burette reading.	
Duration of outflow.	Drainage time.	Total time.	V c.c.	R c.c.	$(V - R)$ c.c.
20 sec.	40 sec.	1 min.	49.89_0	49.99_1	$- 0.10_1$
,, ,,	100 ,,	2 ,,	49.89_0	49.95_0	$- 0.06_0$
,, ,,	180 ,,	3 ,, 20 sec.	49.89_0	49.89_0	0.00_0
,, ,,	280 ,,	5 ,,	49.89_0	49.85_5	$+ 0.03_5$
56 ,,	4 ,,	1 ,,	50.04_0	50.00_0	$+ 0.04_0$
,, ,,	64 ,,	2 ,,	50.04_0	49.99_8	$+ 0.04_2$
,, ,,	180 ,,	3 ,, 56 sec.	50.04_0	49.99_0	$+ 0.05_0$
,, ,,	244 ,,	5 ,,	50.04_0	49.98_4	$+ 0.06_6$
106 ,,	14 ,,	2 ,,	50.09_0	50.00_0	$+ 0.09_0$
,, ,,	180 ,,	4 ,, 46 sec.	50.09_0	49.99_8	$+ 0.09_2$
206 ,,	180 ,,	6 ,, 26 ,,	50.12_6	50.00_0	$+ 0.12_6$

The values given in the last columns of the two above tables show that very considerable errors may result when using a 50 c.c. burette with a delivery time so short as 20 seconds. Variations in the conditions of use given in the above tables, lead to inconsistencies amounting to 0·24 c.c. The burette reading of a 50 c.c. burette calibrated for a delivery time of 20 seconds will only agree with the volume of water delivered if the duration of outflow is equal to the delivery time and a definite time of draining identical with that used in calibration is observed.

The idea that inequalities in the volume delivered, due to variation in the time taken to empty the burette when in use, may be compensated for by allowing a few minutes' drainage before taking the final reading, is incorrect. This may be seen from the above table. For the four examples given in the table for which three minutes' drainage was assumed the values of $V - R$ are as given below.

Duration of outflow.	$(V - R)$ c.c.
20 sec.	0.00_0
56 ,,	$+ 0.05_0$
106 ,,	$+ 0.09_2$
206 ,,	$+ 0.12_6$

Three minutes' drainage is therefore quite inadequate to give consistent results irrespective of the rate of outflow.

Again, taking the examples from Table V where the total time is about five minutes, the values for $(V-R)$ are as given below :

Duration of outflow.	Drainage time.	Total time.	$(V-R)$ c.c.
20 sec.	4 min. 40 sec.	5 min.	$+ 0.03_5$
56 ,,	4 ,, 4 ,,	5 ,,	$+ 0.06_4$
106 ,,	3 ,,	4 ,, 46 sec.	$+ 0.09_2$

The values of $(V-R)$ again differ considerably.

It is clear that no reasonably short drainage time will give constant values for $(V-R)$ when the delivery time of the burette is short, if the time of emptying the burette from the 0 c.c. to the 50 c.c. mark is varied appreciably.

Changes in the rate of outflow are of far more serious consequence than variations in the time allowed for drainage. For example, changing the time of outflow from the 0 c.c. mark to the 50 c.c. mark by only 20 seconds, namely, from 20 seconds to 40 seconds, increases the volume of water delivered by 0.10_8 c.c. It takes as much as three minutes' drainage, however, for this quantity of water to drain from the walls of the burette even when the 50 c.c. interval is emptied in so short a time as 20 seconds.

(3) *N.P.L. Class B Burettes.*—The minimum delivery time which would be allowed for a Class B burette when the length of the graduated portion is the same as that of the burette used in the investigation is 75 seconds. One of the jets used was made to give approximately this delivery time, the actual delivery time being 74 seconds. Suppose the burette to be calibrated so that the volume of water delivered from the 0 c.c. mark to the 50 c.c. mark in 74 seconds agrees with the burette reading, that is, 50·00 c.c., taken immediately after stopping the meniscus on the 50 c.c. mark. The results which would be obtained for the interval 0 c.c. to 50 c.c. with such a burette under various conditions of use are given in the following table :

TABLE VI

Conditions of Use.			Volume of water delivered.	Burette reading.	
Duration of outflow.	Drainage time.	Total time.	V c.c.	R c.c.	$(V-R)$ c.c.
74 sec.	0 sec.	74 sec.	50.00_0	50.00_0	0.00_0
,, ,,	46 ,,	2 min.	50.00_0	49.99_9	$+ 0.00_1$
,, ,,	226 ,,	5 ,,	50.00_0	49.99_5	$+ 0.00_5$
106 ,,	14 ,,	2 ,,	50.02_6	50.00_0	$+ 0.02_6$
,, ,,	194 ,,	5 ,,	50.02_6	49.99_8	$+ 0.02_8$
152 ,,	148 ,,	5 ,,	50.04_6	49.99_9	$+ 0.04_7$
,, ,,	448 ,,	10 ,,	50.04_6	49.99_7	$+ 0.04_9$
206 ,,	94 ,,	5 ,,	50.06_2	50.00_0	$+ 0.06_2$
,, ,,	394 ,,	10 ,,	50.06_2	49.99_9	$+ 0.06_3$

(4) *N.P.L. Class A Burettes.*—The minimum delivery time which would be allowed for a Class A burette having the length of the graduated portion the same as that of the burette used in the investigation is 110 seconds.   One of the jets used was made to give approximately this delivery time, the actual delivery time being 106 seconds.   Suppose the burette to be calibrated so that the volume of water delivered from the 0 c.c. mark to the 50 c.c. mark in 106 seconds, agrees with the reading, that is, 50·00 c.c., taken immediately after stopping the meniscus on the 50 c.c. mark. The results which would be obtained for the interval 0 c.c. to 50 c.c. with such a burette under various conditions of use are given below :

TABLE VII

Conditions of Use.			Volume of water delivered.	Burette reading.	
Duration of outflow.	Drainage time.	Total time.	V c.c	R c.c.	$(V - R)$ c.c.
106 sec.	14 sec.	2 min.	$50 \cdot 00_0$	$50 \cdot 00_0$	$0 \cdot 00_0$
,, ,,	194 ,,	5 ,,	$50 \cdot 00_0$	$49 \cdot 99_8$	$+ 0 \cdot 00_2$
,, ,,	494 ,,	10 ,,	$50 \cdot 00_0$	$49 \cdot 98_9$	$+ 0 \cdot 01_1$
152 ,,	148 ,,	5 ,,	$50 \cdot 02_0$	$49 \cdot 99_9$	$+ 0 \cdot 02_1$
,, ,,	448 ,,	10 ,,	$50 \cdot 02_0$	$49 \cdot 99_7$	$+ 0 \cdot 02_3$
206 ,,	94 ,,	5 ,,	$50 \cdot 03_6$	$50 \cdot 00_0$	$+ 0 \cdot 03_6$
,, ,,	394 ,,	10 ,,	$50 \cdot 03_6$	$49 \cdot 99_9$	$+ 0 \cdot 03_7$

Tables VI and VII show that with both Class A and Class B burettes the errors due to drainage are negligible even for burettes having the minimum delivery times allowed.   They further show that the duration of outflow may considerably exceed the delivery times of the burettes (that is, if necessary, the burettes may be used with stopcock only partly open), without introducing errors in excess of the Class A or Class B tolerances, respectively.

(5) *German Standard Burettes.*—The delivery times specified for German standard burettes are given in the following table.*

TABLE VIII.

Length of graduated portion.			200	350	500	700
{ greater than (mm.)			200	350	500	700
{ not greater than (mm.)		200	350	500	700	1000
Delivery time—seconds.		{ 25	35	45	55	70
		{ to	to	to	to	to
		{ 35	45	55	70	90

In testing the burettes they are emptied from the zero mark, with the tap fully open, until the meniscus is about 5 mm. above the mark to be tested.   A period of 30 seconds is then allowed for

* " Anweisung zur Eichung Chemischer und Physikalischer Messgeräte " (*Ausfuhrungs—bestimmungen zur Bekanntmachung von* 3 Aug., 1909.   **Reichs-Gesetzbl.** 1909, Beilage zu No. 52).

drainage, after which the final setting of the meniscus on the mark to be tested is made.

The length of the graduated portion of the burette used for the results given in Figs. 5 to 10, was 534 mm. According to the German standard requirements its delivery time should be between 55 seconds and 70 seconds.

Assume that the burette reading taken 30 seconds after emptying the burette from the 0 c.c. mark to the 50 c.c. mark, agreed exactly with the volume of water delivered when the interval is emptied in 56 seconds. The 50 c.c. interval of the burette would then be correct according to the German method of test. The following table of results which would be obtained for the interval 0 c.c. to 50 c.c. for various conditions of use, has been derived from Figs. 5 and 6 as previously described.

TABLE IX

Conditions of Use.					Volume of water delivered. V c.c.	Burette reading. R c.c.	$(V - R)$ c.c.
Duration of outflow.	Drainage time.		Total time.				
56 sec.	30 sec.		1 min. 26 sec.		$49 \cdot 99_9$	$49 \cdot 99_9$	$0 \cdot 00_0$
,, ,,	64	,,	2	,,	$49 \cdot 99_9$	$49 \cdot 99_8$	$+ 0 \cdot 00_1$
,, ,,	244	,,	5	,,	$49 \cdot 99_9$	$49 \cdot 98_4$	$+ 0 \cdot 01_5$
,, ,,	544	,,	10	,,	$49 \cdot 99_9$	$49 \cdot 94_4$	$+ 0 \cdot 05_5$
106 ,,	30	,,	2	,, 16 sec.	$50 \cdot 04_9$	$50 \cdot 00_0$	$+ 0 \cdot 04_9$
,, ,,	194	,,	5	,,	$50 \cdot 04_9$	$49 \cdot 99_8$	$+ 0 \cdot 05_1$
,, ,,	494	,,	10	,,	$50 \cdot 04_9$	$49 \cdot 98_9$	$+ 0 \cdot 06_0$
152 ,,	30	,,	3	,, 2 sec.	$50 \cdot 06_3$	$50 \cdot 00_0$	$+ 0 \cdot 06_3$
, ,,	148	,,	5	,,	$50 \cdot 06_9$	$49 \cdot 99_9$	$+ 0 \cdot 07_0$
,, ,,	448	,,	10	,,	$50 \cdot 06_9$	$49 \cdot 99_7$	$+ 0 \cdot 07_2$
206 ,,	30	,,	3	,, 56 sec.	$50 \cdot 08_5$	$50 \cdot 00_0$	$+ 0 \cdot 08_5$
,, ,,	94	,,	5	,,	$50 \cdot 08_5$	$50 \cdot 00_0$	$+ 0 \cdot 08_5$
,, ,,	394	,,	10	,,	$50 \cdot 08_5$	$49 \cdot 99_0$	$+ 0 \cdot 08_6$

The figures in the last column compare unfavourably even with the corresponding figures in Table VI (p. 183), which relate to a Class B burette, and still more unfavourably with the figures for a Class A burette given in Table VII (p. 184).

German standard burettes, therefore, are much less trustworthy in actual use than either the Bureau of Standards or National Physical Laboratory standard burettes, owing to the much greater errors to which they are liable if the conditions of use depart in any way from the conditions of test.

Intervals 0 *c.c. to* 30 *c.c. and* 0 *c.c. to* 10 *c.c.*

The observations described in detail for the interval 0 c.c. to 50 c.c. were repeated for the intervals 0 c.c. to 30 c.c. and 0 c.c. to 10 c.c. The same set of seven jets was used. The results are

FIG. 7.

FIG. 8.

NOTE:—
(1) THE TIME REQUIRED TO EMPTY THE BURETTE FROM THE OcC MARK TO THE 30cc MARK WITH UNRESTRICTED OUTFLOW WAS EQUAL TO APPROXIMATELY 0·5 TIMES THE DELIVERY TIME OF THE BURETTE
(2) VALUES DEDUCED FROM MICROMETER READINGS MARKED ⊙
VALUES DIRECTLY DETERMINED BY WEIGHING MARKED ×

VOLUME OF WATER DELIVERED FROM 0cc TO 30cc MARK WITH UNRESTRICTED FLOW

DELIVERY TIME OF BURETTE (SECONDS)

o 2

FIG. 9.

FIG. 10.

shown in Figs. 7 to 10. Fig. 8 bears the same relation to Fig. 7 that Fig. 6 does to Fig. 5, and Figs. 10 and 9 are similarly related.

The results for the 0 c.c. to 50 c.c. interval having been con sidered in detail, it is only necessary to note the differences between the results for the two additional intervals and those previously onsi dered.

There are two points of difference which may be noted. First, the total amount of drainage for the shorter intervals is, as would be expected, appreciably less than for the longer interval. The second point is that the initial rate of drainage for corresponding jets is greater for the shorter intervals than for the longer one. The rate of drainage increases with the rate at which the water is delivered from the burette. Using any jet, the interval 0 c.c. to 10 c.c. is emptied more quickly than the interval 40 c.c. to 50 c.c. Hence the initial rate of draining is greater when the water surface is stopped on the 10 c.c. mark than when it is stopped on the 50 c.c. mark.

Methods of Using Burettes.

In order to obtain trustworthy results it is essential that burettes should be clean. A good criterion by which to judge the cleanliness of a burette is obtained by filling it slowly through the jet, the burette being held vertical. If the burette is clean the meniscus will rise in the tube without change of shape. Should the meniscus come into contact with a slightly greasy portion of the walls it immediately appears to crinkle at the edges. Further, if the burette is quite clean a thin film of liquid may be seen travelling up the walls of the burette in front of the main water surface. The front edge of this film is clearly visible and forms an excellent indicator as to the cleanliness of the burette. In quite clean burettes the edge of the film advances at the same rate as the meniscus, keeping a uniform distance in front of it. Should the burette be slightly dirty at any point, the front edge of the film is retarded and the meniscus overtakes it and may in turn crinkle up when passing the contaminated surface. A burette which fills up through the jet so that the front edge of the film keeps in advance of the meniscus throughout, may be relied upon to have a uniform film of liquid left on the walls when emptied. The advantage of knowing for certainty when filling a burette that it may be emptied without fear of error due to irregular wetting of the walls is obvious.

Considering now the bearing of the foregoing results on the methods of using burettes, it is quite clear from the results obtained that there are two main sources of error, namely :

(1) The burette reading changes with the length of time which elapses between closing the stopcock and taking the reading.

(2) Variations in the rate of emptying the burette cause variations in the volume of water delivered.

The first source of error may be practically eliminated by making the delivery time sufficiently long. The delivery times specified by the National Physical Laboratory and the Bureau of Standards were chosen so as to minimise errors due to drainage as previously shown on p. 174. That the delivery times chosen are satisfactory for the burette used for the foregoing investigation is shown by Table X.

The volumes given in the body of the table represent the amount of water which drains from the walls of the burette during the drainage time given at the head of the table. The drainage is that which takes place from the intervals specified on the left of the table, after emptying them with unrestricted outflow through jets giving the delivery times (that is, time of emptying from 0 c.c. mark to 50 c.c. mark) stated at the head of the columns.

TABLE X.

Interval.	2 min. drainage.		5 min. drainage.		10 min. drainage.	
	Delivery time 74 sec.	Delivery time 106 sec.	Delivery time 74 sec.	Delivery time 106 sec.	Delivery time 74 sec.	Delivery time 106 sec.
	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.
0 c.c. to 50 c.c.	$0 \cdot 00_2$	$0 \cdot 00_1$	$0 \cdot 00_8$	$0 \cdot 00_4$	$0 \cdot 03_3$	$0 \cdot 01_7$
0 c.c. to 30 c.c.	$0 \cdot 00_4$	$0 \cdot 00_3$	$0 \cdot 02_0$	$0 \cdot 00_9$	$0 \cdot 03_9$	$0 \cdot 02_1$
0 c.c. to 10 c.c.	$0 \cdot 01_1$	$0 \cdot 00_5$	$0 \cdot 01_9$	$0 \cdot 01_2$	$0 \cdot 02_2$	$0 \cdot 01_6$

In connection with the drainage of liquid from the walls of a burette the following may be noted. It is a common practice when using a burette to fill it from the top. The liquid runs down the walls at a considerable speed. Hence a comparatively thick layer of liquid will be left adhering to the walls, since we have seen that considerably more liquid is left on the walls of a burette when it is emptied quickly than when it is emptied slowly. If the initial burette reading is taken shortly after filling the burette from the top, appreciable errors may be introduced by drainage from the walls of the burette left wet above the initial reading. Consequently a burette when filled from the top should be filled to above the graduated portion, and a little liquid run out through the jet to bring the liquid surface on to the graduated portion of the burette near the zero mark before taking the initial reading. If a burette is only partly filled, a considerable length of the burette

is likely to be left wet above the initial reading, and appreciable errors may arise.

The errors arising from the second source mentioned on p. 190, namely, variations in the time of outflow, are also made comparatively small by using burettes having delivery times in accordance with the National Physical Laboratory regulations. In the actual use of a burette, the duration of outflow from the 0 c.c. to the 50 c.c. mark cannot be less than the delivery time of the burette, since the latter is the time of outflow when the stopcock is fully open. If a Class A burette, having the minimum delivery time of 110 seconds and correct when the time of outflow equals the delivery time, that is, when the burette is used with the stopcock fully open, is used with the stopcock only partly open, so that the time taken to empty the burette from the 0 c.c. mark to the 50 c.c. mark is 220 seconds (double the delivery time of the burette), then the resulting error will be approximately 0·04 c.c., or an amount not exceeding the Class A tolerance. Again, if a Class B burette having the minimum delivery time of 75 seconds and correct when used with the stopcock fully open, is used with the stopcock partly open so that the time of outflow from the 0 c.c. mark to the 50 c.c. mark is 220 seconds (the maximum delivery time allowed), the resulting error due to this cause will be approximately 0·06 c.c., or less than the Class B tolerance.

It may be pointed out that in actual practice the errors introduced would most probably be much less than in the examples given in the last paragraph. The specified times of delivery give a rate of outflow, when the stopcock is fully open, which is sufficiently slow for most purposes, and it will rarely be desired to empty the burettes still more slowly.

It will be clear from what has already been said that burettes fulfilling the conditions specified for Bureau of Standards or National Physical Laboratory standard burettes may be used without the necessity of following any rigid method of procedure. The volume of liquid delivered will be practically independent of such variations in manipulation as are often found necessary by the chemist.

For example, it has been shown that drainage is practically negligible with burettes having the specified delivery times. Hence the final burette reading may be taken whenever convenient to the user, within five minutes, or, except when very accurate results are required, even ten minutes after the required amount of liquid has been run from the burette (see Table VIII).

The most accurate results will be obtained if the stopcock is kept fully open wherever possible, but it has been shown on p. 191

that only small errors are introduced if a standard burette is emptied more slowly. It is, of course, not feasible to keep the tap fully open when the end-point of a titration is being approached. The fact, however, that the last cubic centimetre or so is delivered quite slowly is, in effect, simply an introduction of a small drainage time, and this, as we have seen, causes only negligible errors. Moreover, in testing burettes the last cubic centimetre is necessarily run out quite slowly, thus approximating to the conditions of an actual titration.

It may sometimes be desirable to add the reagent from the burette in small quantities at a time. With standard burettes this may be done without fear of serious error, as is shown by the following results.

A burette was emptied from the 0 c.c. to the 50 c.c. mark in the ordinary manner of testing, and the volume of water delivered was determined by weighing. Then the 50 c.c. interval was emptied in a number of different ways. For example, it was emptied with the tap fully open from the 0 c.c. mark to the 25 c.c. mark. The tap was left closed for five seconds and then fully opened and the water run out to the 50 c.c. mark. This procedure was followed and the 50 c.c. interval emptied in a number of different ways, the results being given in the following table for a burette the delivery time of which was 150 seconds. The tap was always turned fully open when water was being run out (except, of course, when making the final setting on the 50 c.c. mark), and each time it was shut off it was allowed to remain closed for five seconds. The results obtained are shown in the following table :

TABLE XI.

Delivery time of burette, 150 seconds.
Volume of water delivered from 0 c.c. to 50 c.c.
in one instalment $= 49.99_6$ c.c. $= V$.

Method of emptying.	Volume of water delivered. V' c.c.	$(V' - V)$ c.c.
50 c.c.	49.99_6	0.00_0
37.5 c.c. + 12.5 c.c.	50.00_1	$+ 0.00_5$
37.5 c.c. + 5 times 2.5 c.c.	50.00_0	$+ 0.00_4$
25 c.c. + 25 c.c.	50.00_1	$+ 0.00_5$
4 times 12.5 c.c.	50.00_1	$+ 0.00_5$
10 ,, 5 c.c.	49.99_9	$+ 0.00_3$
25 ,, 2 c.c.	50.01_4	$+ 0.01_8$
50 ,, 1 c.c.	50.01_6	$+ 0.02_0$

The smallness of the differences in the last column shows that the errors introduced by emptying an interval in fractions is practically negligible when the delivery time of the burette is

within the specified limits. It should be noted that the tap was turned fully open when water was being delivered. The total time during which water was actually flowing from the burette would therefore be approximately the same when the burette was emptied in fractions as when it was emptied continuously. The sources of error would therefore be :

(1) Possible effects of repeated stopping and starting.

(2) Variations due to differing amounts of drainage taking place according to the number of times the tap was closed for five seconds.

Variations from the latter cause would be very small, and hence, since $(V'-V)$ is also small, the effects of stopping and starting are also negligible.

Had the tap not been fully turned on each time greater differences would have been obtained. The rate of outflow from any section would have been reduced below the rate of outflow when the tap is fully open. It has been shown previously, however, that variations due to this cause would be small when the delivery time of the burette is within the specified limits.

It may therefore be concluded that, if any interval on a standard burette is emptied in fractions, the sum of the fractions will be practically the same as the volume delivered when the whole interval is emptied continuously.

The same thing does not hold true for burettes having delivery times appreciably shorter than those specified. The results given in Table XII were obtained with a burette the delivery time of which was 31 seconds, the observations being taken exactly as described above in connection with Table XI.

TABLE XII.

Delivery time of burette, 31 seconds.
Volume of water delivered from 0 c.c. mark to 50 c.c.
mark in one instalment $= 49.94_9$ c.c. $= V$.

Method of emptying.	Volume of water delivered. V' c.c.	$(V' - V)$ c.c.
50 c.c.	49.94_9	0.00_0
37.5 c.c. $+ 12.5$ c.c.	49.95_4	$+ 0.00_5$
37.5 c.c. $+ 5$ times 2.5 c.c.	49.95_4	$+ 0.00_5$
25 c.c. $+ 25$ c.c.	49.95_6	$+ 0.00_7$
4 times 12.5 c.c.	49.95_7	$+ 0.00_8$
10 ,, 5 c.c.	49.96_2	$+ 0.01_3$
25 ,, 2 c.c.	50.00_3	$+ 0.05_2$
50 ,, 1 c.c.	50.04_1	$+ 0.09_2$

The values of $V'-V$ in Table XII are greater than in Table IX, and it should be noted that the most serious cause of error with

burettes of short delivery time, that is, variations in the rate of outflow, was avoided as far as possible by opening the tap fully each time water was run from the burette. Had this not been done considerably greater values would have been obtained for $V' - V$.

When using a burette it is not always convenient to take the zero mark as the initial reading, as is done when burettes are tested. The results given in the following table for a burette the delivery time of which was 150 seconds, show that points other than the zero mark may be taken as the initial reading without introducing appreciable errors when using burettes having a sufficiently long delivery time. Larger values for the differences given in the last column would be obtained with burettes having short delivery times.

TABLE XIII.

Indirect Determination.

20 c.c. Interval.	Interval directly determined.	Volume delivered. A	Interval directly determined.	Volume delivered. B	Value of 20 c.c. Interval = $A - B = V'$	Direct determination. V	Difference. $V - V'$
c.c.	c.c		c.c.				
10—30	0—30	$29 \cdot 98_8$	0—10	$9 \cdot 99_2$	$19 \cdot 99_6$	$20 \cdot 00_4$	$+0 \cdot 00_8$
20—40	0—40	$39 \cdot 98_3$	0—20	$19 \cdot 97_8$	$20 \cdot 00_5$	$20 \cdot 00_0$	$-0 \cdot 00_5$
	10—40	$29 \cdot 99_0$	10—20	$9 \cdot 98_4$	$20 \cdot 00_6$		$-0 \cdot 00_6$
30—50	0—50	$49 \cdot 99_6$	0—30	$29 \cdot 98_8$	$20 \cdot 00_8$		$-0 \cdot 00_8$
	10—50	$40 \cdot 00_5$	10—30	$20 \cdot 00_4$	$20 \cdot 00_1$	$20 \cdot 00_0$	$-0 \cdot 00_1$
	20—50	$30 \cdot 02_1$	20—30	$10 \cdot 01_3$	$20 \cdot 00_8$		$-0 \cdot 00_8$

When it is considered that the quantity $V - V'$ is based on three independent experimental observations, each, of course, subject to experimental error, the smallness of the values $V - V'$ shows that the correction for a given interval of a standard burette may be deduced from the known corrections of two other intervals with a satisfactory degree of accuracy. For example, if the 0 c.c. to 30 c.c. interval were certified as 30·01 c.c. and the 0 c.c. to 50 c.c. interval as 49·99 c.c., then 19·98 c.c. may safely be taken as the value for the 30 c.c. to 50 c.c. interval, if 30 c.c. were taken as the initial reading and 50 c.c. as the final reading in any determination.

Another point in connection with the use of standard burettes may be mentioned. When using burettes with short delivery times it is customary to wait several minutes before taking the final burette reading if accurate results are required.* Although the delivery times specified for standard burettes are longer than were formerly, and to a large extent still are, employed, yet since

* For comments on this practice, see page 182.

no period of waiting for drainage is necessary with the longer delivery times, the time occupied by a titration is not increased.

Use of Liquids other than Water.

When in actual use a burette is rarely employed to measure volumes of water. The results given above relate solely to water, and the question arises how far they are applicable to other liquids ordinarily measured by means of burettes. It is intended to carry out a detailed investigation of this question as soon as there is an opportunity for doing so. The following remarks may, however, be noted.

If burettes with short delivery times are used they will be liable to similar inconsistencies for all liquids as have been shown to occur when water is delivered from them. Further, the differences between the delivered volumes of two different liquids corresponding to identical burette readings will be greater with burettes having short delivery times than with burettes having long delivery times. It is, however, tolerably certain that a burette which has a delivery time in accordance with the Bureau of Standards or the National Physical Laboratory specifications, and has been calibrated with water, may be used for the majority of dilute aqueous solutions used in volumetric analysis without the risk of serious errors.

A few determinations have been made of the volumes of water, alcohol, and concentrated sulphuric acid delivered from a 50 c.c. burette, and the results are given in the following table :

TABLE XIV.

Interval. c.c.	Water.		Alcohol.		Concentrated sulphuric acid.	
	Time of outflow at 18°.	Volume delivered at 18°.	Time of outflow at 18°.	Volume delivered at 18°.	Time of outflow at 18°.	Volume delivered at 18°.
0—10	18 sec.	9·95 c.c.	19 sec.	9·93 c.c.	36 sec.	9·89 c.c.
0—30	60 ,,	29·97 c.c.	63 ,,	29·92 c.c.	129 ,,	29·80 c.c.
0—50	126 ,,	49·94 c.c.	132 ,,	49·87 c.c.	305 ,,	49·71 c.c.

The differences between the volumes of alcohol and water delivered are 0·02 c.c., 0·05 c.c., and 0·07 c.c. for the 10 c.c., 30 c.c., and 50 c.c. intervals, respectively, less alcohol than water being delivered. Part of the observed differences is due to the evaporation of alcohol during the time that the liquid was being run out from the burette. The alcohol was collected in a beaker

which was covered with a watch glass immediately the final setting of the alcohol surface in the burette had been made.   The volume of alcohol then contained in the beaker was determined by weighing.   This volume would be less than that delivered from the burette by an amount equal to the volume of alcohol evaporated from the surface of the liquid in the beaker, and from the liquid issuing from the jet of the burette.

It was found that 50 c.c. of alcohol left in the uncovered beaker lost 0·024 c.c. in five minutes, which corresponds approximately with 0·01 c.c. during the time taken to empty 50 c.c. from the burette.

A pipette with a spherical bulb was made to hold approximately 50 c.c. of alcohol.   It was filed with alcohol and suspended from one arm of a balance, its lower end being over an empty beaker placed on the scale pan of the balance.   The balance was counterpoised and the alcohol then allowed to flow from the pipette into the beaker, the time occupied by the transfer being approximately equal to that required to empty 50 c.c. of alcohol from the burette. The balance was again counterpoised immediately the alcohol had been run into the beaker.   The loss in weight observed was equivalent to a loss of approximately 0·03 c.c. of alcohol.

The above values for the loss of alcohol due to evaporation cannot be used to correct the observations of the volume of alcohol delivered from the burette, since the conditions are not strictly comparable.   They indicate, however, that the difference between the measured volumes of alcohol and water delivered from the burette is not wholly due to the burette functioning differently with the two different liquids.   An appreciable portion of the observed difference is doubtless due to evaporation of the alcohol.

The differences between the volumes of strong sulphuric acid and water delivered were 0·06 c.c., 0·17 c.c., and 0·23 c.c. for the 10 c.c., 30 c.c., and 50 c.c. intervals, respectively.

It was found that 50 c.c. of the acid exposed in a beaker gained only 0·016 gm. in weight in a quarter of an hour.   The amount of water vapour absorbed by the acid was therefore too small to exert any appreciable influence on the values obtained for the volume of acid delivered from the burette.   From the results obtained it is clear that, should it be desired to measure volumes of concentrated sulphuric acid from a burette, the burette should be calibrated with acid of the strength desired.

Alcohol and strong sulphuric acid were chosen for the above preliminary experiments because their physical properties differ considerably from those of water, as may be seen from the values given in the table below :

TABLE XV.

Physical constants at 18°.	Water.	Alcohol.	Sulphuric acid.
Density in gm. per c.c.	0·9986	0·8103	1·8379
Surface Tension in dynes per cm.	73	23	55
Viscosity in centipoises.	1·03	1·55	26·6

The above values were determined on the samples of alcohol and acid used with the burette. Compared with water the alcohol has a low density, low surface tension, and slightly higher viscosity, and the sulphuric acid a high density, high viscosity, and somewhat lower surface tension. The dilute aqueous solutions ordinarily employed in volumetric analysis are not nearly so different from water in their physical properties as are alcohol and sulphuric acid. The differences obtained between the volumes of water and of alcohol and sulphuric acid, respectively, delivered from the burette may therefore be expected to be considerably greater than the differences likely to be obtained with aqueous solutions of the strengths ordinarily employed in volumetric analysis.

The following comparison is of interest. By varying the conditions of use, differences amounting to 0·24 c.c. (see Tables IV and V) may be produced in the volume of water delivered from the 0 c.c. to 50 c.c. interval of a 50 c.c. burette having a delivery time of 20 seconds. With the burette having a delivery time of 126 seconds used to obtain the results given in Table XII, 0·23 c.c. less sulphuric acid was delivered from the 50 c.c. interval, the stopcock being fully open both for the acid and the water except when making the final setting on the 50 c.c. mark.

Hence, by simply varying the conditions of use of a 50 c.c. burette having a delivery time of 20 seconds, as great variations may occur in the volume of water delivered as the differences between the volumes of sulphuric acid and water when using a burette having a delivery time of approximately 120 seconds.

Volumetric Methods of Testing Burettes.

A typical example of volumetric methods of testing burettes is that due to Ostwald and described in many text-books. The burette is connected to a small pipette which has a graduated stem above the bulb. The pipette is filled from the burette through a connecting tube, and the errors of the burette deduced from the burette and pipette readings and the known capacity of the pipette.

From the results which have already been described, it is clear that if the rate at which any interval is emptied when the burette

is connected to the pipette, differs from the rate of outflow from the burette when it is delivering freely, then the results obtained in the calibration may differ greatly from the volumes actually delivered by the burette when in normal use.

Gravimetric methods of test are much more trustworthy, and have been adopted by the National Physical Laboratory, the Bureau of Standards, and the Reichsanstalt.

Volumetric methods may be made much more rapid than gravimetric ones, and hence burettes are nearly always " pointed " volumetrically when manufactured.

It is essential, however, in working out the details of a volumetric method that careful consideration should be given to the two important sources of error, namely :

(1) Changes in the volume delivered with change in delivery time ;
(2) Changes in burette reading due to drainage ;

particular attention being directed to the former.   Further, the burettes must be provided with jets which give a delivery time suitable to the method of calibration employed.   It is hoped that the data given in this paper may prove helpful to manufacturers in working out details of calibration by volumetric methods.   A series of investigations is in progress from which similar data for the various sizes of tubing used for burettes and graduated pipettes will be obtained.

It is also perhaps worth while pointing out, what is very evident from the results given previously, that should the jet of a burette be damaged in the course of use so that the delivery time is appreciably altered, then the burette should either be re-tested for the new rate of delivery, or, preferably, repaired so as to give the original delivery time.   Burettes are not accepted for test at the National Physical Laboratory unless the delivery time is etched on them.

In conclusion, the author desires to express his thanks to Mr. J. E. Sears, jun., for helpful criticisms during the preparation of the above paper, and to the Director of the National Physical Laboratory for permission to publish the results obtained.   The experimental work on which Figs. 5 to 10 are based was carried out by Mr. C. W. Wells under the direction of the author.

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XVII.—*On the Refractive Index Changes in Optical Glass occasioned by Chilling and Tempering.*

By F. Twyman, F.Inst.P., and F. Simeon, B.Sc., F.Inst.P.

Introduction.

It has long been known that the two processes of chilling and tempering produce important changes in the structure and properties of metals, the best known instance being that of the hardening and tempering of steel. It is therefore to be expected, as glass has elastic properties analogous to those of metals, that similar heat treatment will in this case also produce changes which might well be indicated by a change of refractive index. Indeed for many years it has been known that fine-annealed glass may have a refractive index different from that of the same glass before fine annealing, a fact which suggests that the chilling of glass might produce peculiar properties. The well-known strengthening of glass objects produced by chilling them superficially while within or above the annealing range might also be a case in point, although a plausible explanation is afforded by the state of compression known to be occasioned in the outer layer by such a process.

Some definition of the terms " chilling " and " tempering " as used by the authors, more particularly as applied to glass, is desirable. By " chilling " is meant the rapid cooling from a high temperature as opposed to the controlled cooling from a medium temperature known as " annealing." In the case of a metal, rapid cooling is usually effected by immersing it at a red heat in water or in oil. Such treatment in the case of glass would, in most cases, produce internal stresses sufficient to shatter it completely, but considerable " chilling " can be effected by allowing the glass to cool in air from a temperature within or above the annealing range.

The process of tempering a metal consists in the removal of a part of the properties introduced in the preceding operation by heating it to a definite temperature very considerably lower than that attained for " chilling," and allowing it to cool slowly. The degree of this temperature depends to some extent on the time for which the metal is maintained at the chosen temperature, but there is a limiting value to the tempering obtainable at each temperature. Throughout this report the term " tempering " will be

applied to the analogous partial recovery of the properties of glass in the annealed state on heating to a medium temperature.

A word may conveniently be said here concerning annealing. The meaning of the term as applied to glass is well known, but, as in this report a definite temperature is always meant when the term " annealing temperature " is used, it is necessary to explain what this temperature is, namely, that at which internal stresses existing in the glass are reduced to 1/20 of their original amount in 0·26 minute.*

The phrase " full annealing refractive index " is used to indicate the limit to which the refractive index measured at atmospheric temperature tends in the case of a glass which has been maintained for a longer and longer time at its annealing temperature, the cooling in each case being at a controlled rate (defined later).

Scheme of Work.

A number of optical glasses were selected embracing most types used for components of optical systems and including some extra dense flint glasses used in spectroscopy. This paper deals, however, only with measurements made on two of these, namely, a Dense Barium Crown, which was expected to show the effect more markedly than other glasses (this expectation being justified by a cursory investigation of the range of glasses chosen), and a Borosilicate Crown.

The particulars of these glasses are as follows :—

1. *Dense Barium Crown.*

   Maker .... Chance.
   Melting No............................ 3271.
   μ_D (annealed value) .... 1·5990.
   Annealing temperature .... 591·3°.
   Supplied in moulded blocks.

2. *Borosilicate Crown.*

   Source .... Brit. Sci. Instr. Research
   Association.
   Identification .... " Third Cast."
   μ_D (annealed value) .... 1·5074.
   Annealing temperature .... 565°.
   Supplied in a polished plate.

For each of these glasses the change of refractive index caused by cooling it as quickly as possible without shattering the glass

* The method of determining this temperature is that described by one of the authors (This Journal, TRANS. 1917, **1**, 61).

was found. The rate of recovery and the amount of this recovery were then determined at each of three different temperatures, the specimen being raised to the chosen temperature by an electric furnace, and kept at that temperature for a given length of time. The measurement of refractive index was made at room temperature after suitable cooling. Measurements were made for sodium light ($\lambda = 5890$ Å.) only.

The Apparatus.

The electric furnace used was of the common tubular resistance type. The specimen was placed as nearly as possible centrally in the furnace, and the ends were filled with asbestos wool and closed by uralite plates. The temperatures were, in general, read by a platinum resistance thermometer connected to a Callendar recorder, although in some of the earlier work use was made of a thermo-electric pyrometer in conjunction with a galvanometer calibrated to read temperature directly. Refractive index measurements were made with a Pulfrich refractometer. With this instrument, absolute measurements could be made with an accuracy of ± 0.00005, whilst difference measurements within the range of the micrometer screw motion would be accurate to about ± 0.00002. Measurements of the former kind were made in the case of the Dense Barium Crown glass, and of the latter in the case of the Borosilicate Crown. For this glass, a prepared test-piece of the original glass was placed on the refractometer prism together with the sample under test, in order to provide a datum reading. The surfaces of the test-piece undergoing tempering were always reworked whenever they became so distorted during heating as to show more than two interference bands when placed in position on the refractometer prism.

Experimental.

A preliminary series of measurements was made in the case of the Dense Barium Crown in order to determine the amount of the effect to be expected from chilling and tempering, and the limits within which tempering takes place. A piece of glass about 1 cm. square and $\frac{1}{2}$ cm. thick was heated on a thin sheet of iron until the surface began to flow, when the flame was removed. The rate of cooling was such as to produce internal stresses sufficient to fracture the glass, but not to shatter it completely. One part of the glass was polished and measured, the change in refractive index being a decrease of about 0.005. This was the maximum change produced. Efforts to cause chilling by heating the specimen in the furnace to above the annealing temperature and allowing it to

fall on to a surface at atmospheric temperature were unsuccessful in producing a change measurable by the method described.

The chilled sample was now subjected to a number of temperings (twenty in all) at temperatures ranging from 460° to the annealing temperature (591°). From the results obtained, it was seen that the effect of tempering could be well shown by measurements of the rate of tempering at each of three temperatures, of which the annealing temperature is the highest.

The rate of tempering at any temperature was determined as follows : A piece of chilled glass was put into the furnace and raised to the required temperature, which was maintained for a few minutes only, and the furnace allowed to cool at a controlled rate. The refractive index of the specimen was determined when cold, the surfaces being reworked if necessary. The glass was then again subjected to the same treatment, but this time the furnace was maintained at the temperature in question for, say, one hour before cooling commenced. This process was repeated for various intervals of time until no change was found.

A word should be said here concerning the rate of cooling adopted. Twyman * has shown that it is only within a comparatively small range of temperature, close to the annealing temperature as defined above, that it is imperative to adopt a slow rate of cooling if the object be to render a homogeneous sample free from elastic stress. Results good from the last-named point of view can be obtained, in the size of pieces now in question, by cooling at the rates given by the formula :—

$$\theta_0 - \theta = e^{at}$$

in which
θ_0 = annealing temperature,
θ = actual temperature at time t,
and a is a constant.

The value of a actually used is such as would give a fall of temperature of 200° in four hours. This, then, was the mode of cooling aimed at. Such a rate does not, of course, produce any " chilling " effect, whilst in the practice of annealing optical glass the rate would be much less.

According to this rule, the actual rates of cooling are as follows :—

Immediately below the annealing temperature, 1° in fifteen minutes, or 4° per hour.

At 60° below this temperature, 1° in 0·75 minute, or 80° per hour.

And at 120° below, 1° in 0·4 minute, or nearly 160° per hour.

This means that care in cooling was required only in experiments

* This Journal, TRANS., 1917, **1**, 61.

made close to the annealing temperature. In other cases the lagging of the furnace was sufficient to prevent the rates given being exceeded. The actual rate was, in fact, considerably less than that given by the formula.

The Results for the Dense Barium Crown, 3271.

Tempering curves for this glass corresponding with the temperatures 460°, 520°, and 591° (the annealing temperature) are given in the accompanying diagram (Fig. 1). It will be seen by reference to these curves that at the lowest temperature the total recovery of refractive index is very small and is very quickly attained. At the intermediate temperature, almost any value of refractive index
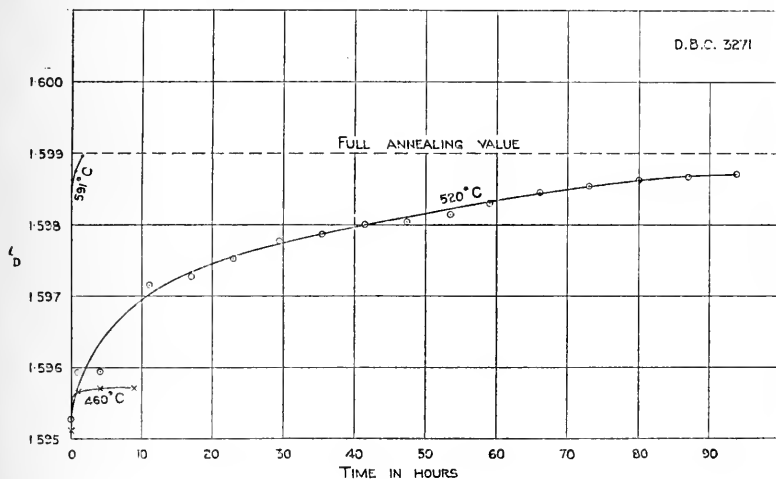
FIG. 1.

between the chilled and the full annealing values can be obtained by suitable choice of the time for which the glass is maintained at this temperature. Within close limits, the annealed value is attained by raising to the annealing temperature for two hours, and cooling as described.

A difficulty was encountered with this glass which necessitated a further series of experiments for its solution. Repeated annealings gave values of refractive index varying between 1·59880 and 1·59915, whilst measurements made on two pieces cut from the same original block of glass gave the values 1·60032 and 1·60029 respectively. It was at first thought that, to allow the glass to re-attain its full original refractive index, a higher temperature might be required than is necessary to fine anneal it. Repeated heating to 610° combined with specially slow cooling to below the

annealing temperature failed, however, to yield a value higher than the full annealing value.

The fact that the original piece of glass was taken from the surface of a moulded block suggested that pressure during some part of the cooling might have an effect, at any rate so far as the surface layers are concerned. Accordingly the following experiments were made to test this point :—

(1) Another test-piece was made from the original block of glass, the observed value of the refractive index being 1·60000.

(2) This test-piece was fully annealed in the usual way, and μ_D found to be 1·59880.

FIG. 2.
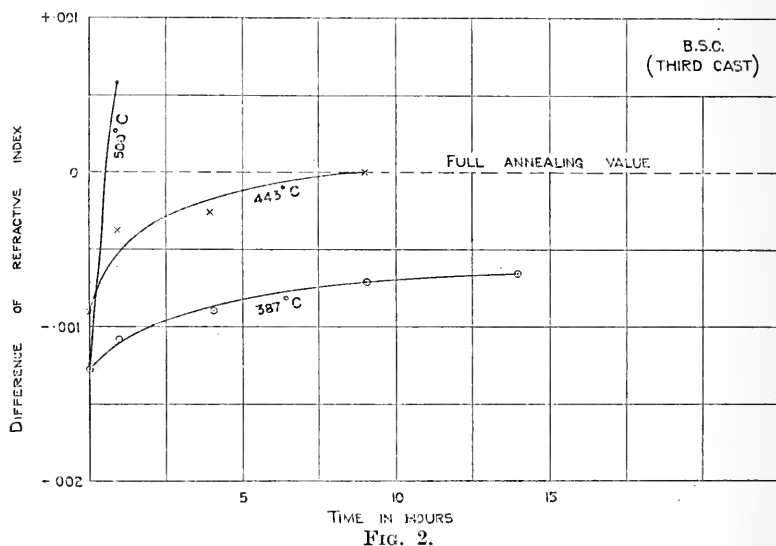
(3) It was edged to a circular disc of $\frac{1}{2}''$ diameter, placed in a metal cylinder under a pressure of 13 lb./in.^{2} (0·09 kg./cm.^{2}) and again fully annealed. The refractive index was now 1·59935.

(4) When placed under a pressure of 60 lb./in.^{2} (4·2 kg./cm.^{2}) and again annealed, μ_D became 1·59940.

(5) The specimen was well packed in magnesia, not under pressure, and raised to a temperature of 654°, cooled to 615°, and kept at that temperature for about $\frac{1}{2}$ hour and then cooled at 5° per hour to 591° and annealed; μ_D became 1·5990.

(6) Test (5) was repeated with the same result.

(7) Another piece of the original block was placed under pressure of 80 lb./in.^{2} (5·2 kg./cm.^{2}) and fully annealed. The refractive index was reduced from 1·6000 to 1·5993.

It would seem, therefore, that for this kind of glass the con-

dition of internal stress during cooling is also an important factor in determining its possible variation of refractive index.

The lowering of refractive index on chilling cannot be due to the tension of the inner region present in the chilled glass for the reasons : * (a) The Pulfrich prism being sharp-edged, the refractive index of the chilled surface itself (or within $\frac{1}{2}$ mm. of the same) was observed. If stressed at all this must have been in compression. (b) The tension which the glass would withstand (say 500 kg./cm.^{2}) without fracture would only cause a lowering of refractive index of the order 0·0002.

To make ourselves quite clear, our suggestion is that in mould-
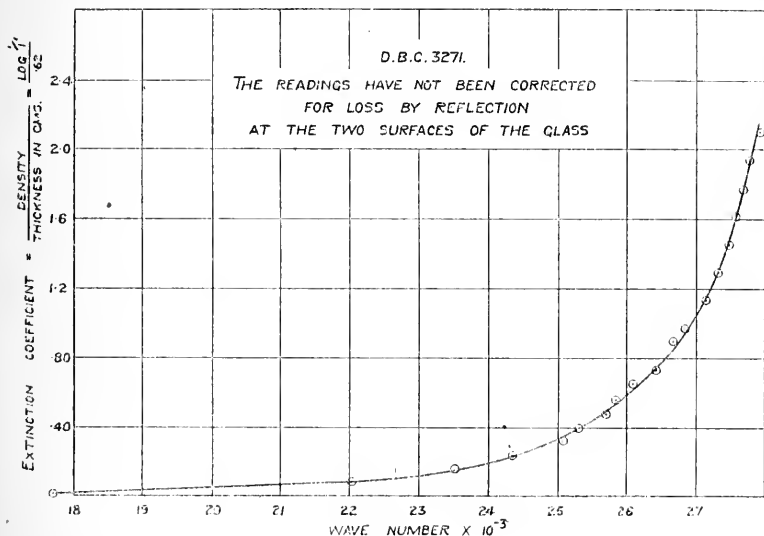
Fig. 3.

ing this block of D.B.C., (a) the considerable pressure, partly due to the mould and partly to the compression caused by chilling the outer surface, produced a state of the material characterised by high refractive index, and that the glass set in this condition; (b) the chilling probably produced, as in our experiments, its customary effect of lowering the refractive index; (c) the annealing process used by the glass-maker was sufficient to remove effect (b), but not effect (a), leaving the glass with a higher refractive index than that proper to it when fully annealed without pressure.

* The stress optical coefficient of the glass used and the actual stress present should, in our opinion, be measured in every case if it be intended to settle quite without doubt these minor points.

Results for the Borosilicate Crown.

The tempering curves of a chilled specimen are given for the temperatures 387°, 443°, and 500° (Fig. 2). It will be noticed that by annealing the chilled specimen from 500° the index is higher than at the annealing temperature. This result was repeated, and it was also shown that very little change in the refractive index of the original glass was caused by annealing, the actual change being a decrease of about 0·00006.

In addition, one specimen which had been annealed from 500°, and which consequently had a refractive index higher than the full annealing value, was fine annealed at 565°. The refractive index
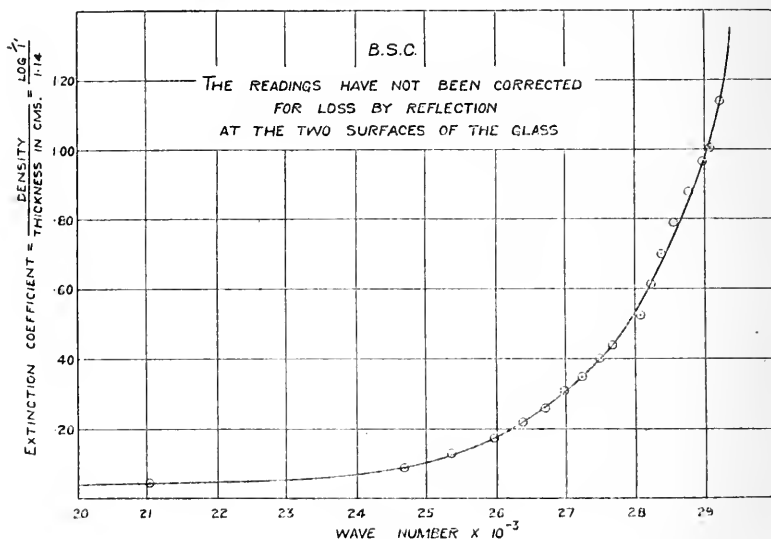
FIG. 4.

was, as a result of this treatment, again reduced to the full annealing value.

Absorption Measurements.

It was considered of interest to examine the limits of absorption of the ultra-violet by these glasses. This was done by means of a Hilger Quartz Spectrograph, E. 3, and Sector Photometer. Curves are given (Figs. 3 and 4) showing the connection between the extinction-coefficient and wave-number. As the glass was placed in the beam of the invariable sector without any compensation in the other beam, the curves are not corrected for reflection from the surfaces of the glass.

Conclusions.

(1) It has been established that the effect of chilling the D.B.C. and B.S.C. samples referred to may be the lowering of the refractive index by as much as 0·004 in the case of the former and 0·0013 in the case of the latter.

(2) This lowering of refractive index is removable by heating to a temperature and for a length of time which have been ascertained for certain cases.

(3) It has been found in the case of the D.B.C. that if the glass be cooled from the annealing temperature slowly under pressure and measured not under pressure, the resulting refractive index is higher than when it is similarly cooled free from pressure, by amounts of the order of 0·00035.

(4) The effect under (3) above seems to us to require further investigation for its complete elucidation, but for practical purposes the main effect of the chilling alone appears of importance.

(5) It is clear that a want of homogeneity could be produced by moulding, owing to surface chilling, which requires for its removal a longer maintenance at the high temperature than will suffice to remove elastic stress from a homogeneous sample.

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XVIII.—*Some Observations on the Corrosion of Fireclay Materials by Alkali Salts.*

By DONALD TURNER, B.Sc.Tech. (sometime Salters' Research Fellow), and W. E. S. TURNER, D.Sc.

THE observations recorded in this paper were made during 1920 and 1921. They are, unfortunately, incomplete, and the opportunity to carry them to a further stage has not subsequently presented itself. It is considered, however, that incomplete as they are, they may not be without suggestiveness to glass manufacturers, to makers of refractory materials, and in particular to other investigators in this same field.

Some of the experiments touch on subjects about which opinions have been previously expressed, but without any basis of systematic experiment. In attempting to apply tests so as to acquire

experimental evidence we do not feel that we have been passing over well-explored ground.

The corrosion of fireclay materials is a matter of very considerable complexity. In the first place, fireclay itself has no definite chemical composition, being a mixture involving the presence, not only of the so-called clay substance itself, with a theoretical formula $Al_2O_3,2SiO_2,2H_2O$, but also of various foreign substances varying in amount, both absolute and relative, such as, on the one hand, quartz, mica, felspar, which may be more or less useful, and iron-bearing minerals, such as iron pyrites and limonite, on the other, which for the main part are detrimental.

Thus, the glass manufacturer is quite conversant with the pitting of pots or bricks when the clay from which they were made has not been satisfactorily picked and iron pyrites eliminated.* H. V. Thompson has also shown that the corrosive action of salt on clays increases with the iron content.†

All these different constituents present in clay have their own rates of solution and the corrosion of the fireclay as a whole will depend, therefore, not only on their actual amount, but also on the size of the particles and their distribution.

Not only is the raw clay itself, accordingly, a highly composite body, but prepared fireclay materials are composite in that they contain at least two essential constituents, namely, the newly burnt clay on the one hand, and the grog on the other, the latter having received at least one more firing than the newly burnt clay, and usually having been heated to a higher temperature. The texture of the manufactured particle is therefore composite, and the grog has usually a smaller porosity and a greater resistance to corrosion than the body. Differential solution is liable to take place and any fluctuations of temperature may also help to disintegrate the body, loosening the grog from its matrix, and thus opening the way for extensive chemical attack.

The low conductivity of fireclay material likewise results occasionally in difficulties in the firing, which in turn produces in any one body portions of different hardness and therefore of different resistance to corrosion.

The Nature of Corrosion.

Turning to the process of corrosion itself, at least two factors come into operation in practice, namely, those which we may describe, respectively, as the mechanical and the chemical.

The mechanical factors include such phenomena as convection

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* See, for example, Gorton, *J. Amer. Cer. Soc.*, 1918, **1**, 648.

† *Trans Cer. Soc.*, 1917—1918, **17**, 340.

currents due to temperature differences in the different portions of the glass or slag in contact with the refractory material. That these convection currents may play an important part in the operation of corrosion has been shown by the experiments of E. A. Coad-Pryor * and W. Rosenhain.†

In actual practice, we have on various occasions seen the production of a distinctly indented ring at the glass level which may be evidence of this convection movement referred to by Coad-Pryor and Rosenhain and may also be associated with the mechanical action of the bursting of gas bubbles at that point. Other evidence of mechanical factors is seen in tank furnaces, such as the additional corrosion occurring through the rise and fall of the glass level, whilst the speeding up of production from glass tank furnaces has led to numerous cases of corrosion of the tank blocks which must be associated with the more rapid flow of the glass through the tank.

The actual chemical action, which will differ with the nature of the materials composing the batch, is also obviously influenced by temperature, and by the mechanical factors already mentioned. The rate of diffusion has a most important influence in all chemical actions, and the flow of glass through a tank furnace, whilst it may conceivably produce a certain amount of abrasion, especially by washing away larger grog particles, may also cause increased corrosion by the more rapid removal of the aluminous layers of glass, the products of solution, from the sides of the furnace and the bringing up of a fresh supply of glass ready for further attack.

It will be recognised from all these remarks that investigations on corrosion are beset with many and complex factors.

In our own experiments we have concentrated mainly on the chemical side of the problem, although certain other factors, such as the temperature and the porosity of the refractory material, have of necessity had to be taken into account as well as the specific action of the reagent itself.

The Attack of Batch Constituents on Fireclay Refractory Materials.

Little is known with any degree of preciseness about the action of the individual materials used for the preparation of glass batches, although some factors are fairly generally recognised.

The action of common salt has received some slight examination because of its importance in connection with the durability of coke oven-walls. Thus, J. W. Cobb ‡ has shown that the action of

* This Journal, TRANS., 1918, 2, 285.

† Ibid., 1919, 3, 93.

‡ Gas Journal, 1916, 133, 684. See also W. J. Rees, J. Soc. Chem. Ind., 1920, 39, 197T.

sodium chloride on finely divided fireclay is to produce a sodium aluminium silicate corresponding with $Na_2O,2Al_2O_3,7SiO_2$.

It seemed to us desirable, if it could be accomplished, to obtain some more definite information about the individual action of the more important materials used in glass-making practice, materials such as soda ash, potash, sodium nitrate, potassium nitrate, sodium sulphate and borax, and to this end the observations recorded in this paper were directed.

The Corrosive Action of Alkali Salts on Burnt Fireclay.

A method which seemed to us capable of application consisted in heating together mixtures of fireclay grog, prepared in a definite manner, and the particular alkali salt in a crucible of non-corrodible material. Such tests might be carried out at a series of different temperatures for a definite time and the extent of corrosion determined by washing out the residual salt and ascertaining either the amount of refractory material taken up by the salt, or, alternatively, the loss in weight sustained by the fireclay. As we shall see, the method was by no means so simple as it at first sight appeared, and it has so far had but limited application by us.

Four different clays were used by us in various experiments, namely, a Stourbridge clay, one from Halifax, and others from Mansfield and Ayrshire, respectively, the composition being as follows :

TABLE I.

Percentage Composition of the Raw Clays.

	Stourbridge No. 1.	Halifax No. 2.	Mansfield.	Ayrshire.
SiO_2	68·50	70·40	45·20	36·35
Al_2O_3	20·20	17·92	35·62	45·01
Fe_2O_3	1·29	2·14	2·43	1·00
TiO_2	1·33	1·18	1·19	2·84
CaO	0·32	0·12	0·46	—
MgO	0·27	0·37	—	—
K_2O	0·79	0·83	0·85	0·29
Na_2O	0·38	0·15	0·98	0·30
Loss on ignition	7·51	7·35	13·27	14·13

The physical characteristics of these clays have been fully described in a paper * from this laboratory, and the samples used here were drawn from the same stock as was employed in the measurements of the physical properties.

The crushed clay sieved through a 30-mesh sieve was made up

* E. M. Firth, F. W. Hodkin, and W. E. S. Turner, this Journal, TRANS., 1920, **4**, 162; E. M. Firth and W. E. S. Turner, *ibid.*, 1921, **5**, 268.

into the form of slabs and fired to a definite temperature in an electric furnace. The temperature of firing was either 1,300° or 1,400°. The slabs, after being fired, were crushed and sieved between 16- and 20-mesh, and this particular grading was selected for examination. The grog was magnetically treated to remove any traces of iron acquired during the crushing process.

Twenty gms. of dried batch material and 1 gm. of thoroughly dried grog were mixed in a nickel crucible and heated in an electric furnace for three hours, the extreme temperature readings usually being less than 5° apart.

The first temperature chosen for test was 800°. After the heating, the crucible was cooled in a desiccator and weighed to ascertain the loss due to volatilisation. In some cases, such as with sodium and potassium carbonate, the loss was also checked by titrating the residue or a portion from it.

The residue was extracted thoroughly with water, the grog treated for a short time with dilute hydrochloric acid to remove the adhering alumina, and after titration the solution was analysed whilst the grog itself was ignited and weighed.

The following results were obtained in the way described, using grog obtained by burning Stourbridge clay at 1,400° and heating it with the batch material for three hours at 800°.

TABLE II.

Corrosive Action at 800° of Alkali Salts on Grog from Stourbridge Clay Prepared at 1,400°.

Batch material.	Melting Point.	Per cent. loss in wt. of grog.	Per cent. Al_2O_3 and Fe_2O_3 dissolved out.	Per cent. loss by volatilisation.	Remarks.
Sodium carbonate ...	853°	3·7	8·00	1·9	Incipient fusion of carbonate.
Potassium carbonate	885°	11·5	9·00	4·5	Incipient fusion of carbonate.
Sodium sulphate	885°	0·47 increase.	—	0·1	No sign of fusion.
Sodium nitrate	308°	42·2	12·6	6·9	Fused. Slight attack on crucible.
Potassium nitrate ...	339°	61·3	—	15·8	Fused. Marked attack on crucible.
Borax	742°	Fused, and crept over the sides of the crucible. Formed glass with grog which could not be removed from crucible. By size of grains left obviously more attack than in previous experiments.

The extensiveness of attack on very hard burnt grog at so low a temperature as 800° was to us surprising. It will be noted that the potassium salt was in each case distinctly more corrosive than the corresponding sodium salt. No quantitative measurement was

obtained with the borax, but it appeared even more corrosive than any of the other salts.

We have used the term " quantitative measurement " for convenience, yet fully recognising that no certain basis of quantitative measurement has been established by us in these experiments. The alumina and iron oxide extracted is in the case of the sodium carbonate more than twice the loss in weight apparently sustained by the grog, whilst in all cases the ratio of these two oxides to the total loss is greater than indicated by the percentage of the oxides in the fired clay. The phenomenon is similar to the absorption by inferior glass of water to such an extent that although alkali is abstracted there appears to have been a gain in weight by the glass. It appears, therefore, that the fired clay absorbs the alkali salt and either retains it tenaciously so that it is not extracted by water and dilute hydrochloric acid, or, more probably, a reaction occurs in which readily soluble sodium (or potassium) aluminate is produced together with a silicate, possibly alkali–alumina silicate, which remains invulnerable to water and dilute acid.

In the circumstances, the loss in weight sustained by the grog cannot be the true, although it may conceivably be a comparative measure of corrosion. All the data recorded under the different headings of Table II do concur generally in indicating the order of corrosion. The percentage loss by volatilisation is not to be regarded as due to vaporisation of the alkali salt, but as corresponding with the amount of reaction and the evolution of gas in the case of the carbonates and nitrates.

The result with sodium sulphate indicates absorption, but with very slight or no reaction. The melting point of the sulphate is not far removed from that of sodium carbonate, and certainly at the much higher temperatures of glass furnaces, salt-cake batches have usually been regarded as more corrosive than similar batches containing soda ash only.

Repetition of some of the experiments showed that distinctly different results could be obtained in repeated experiments under ostensibly the same conditions. It was considered possible that variation of the surface area of the grog might influence the result in different experiments. Accordingly, an experiment was made using Ayrshire clay, and grog was prepared from it fired at 1,400°. This was treated at 800° for three hours with sodium carbonate in the manner already described, experiments being repeated with both rounded grains and flat, angular grains selected from the size lying between 16- and 20-mesh. Table III sets out the results of eight tests, in four of which grains of mixed form were used and four in which rounded were tested in comparison with flat grains.

Table III.

Attack of Sodium Carbonate at 800° on Grog from Ayrshire Clay.
Duration of Experiment, 3 hours.

	Percentage loss in weight.	Remarks.
1	18·83	
2	11·09	
3	11·92	
4	13·64	
5	14·99	Rounded grog grains.
6	17·10	Flat, angular grains.
7	17·25	Rounded grog grains.
8	15·95	Flat, angular grains.

Fluctuations were still found which could not be accounted for by the difference in grain shape, as will be evident from the table. We did find that the reaction was very sensitive to temperature variation, a distinctly greater attack occurring even when the temperature rose 3° or 4° only, and we were led accordingly to test the influence of temperature by carrying out some experiments at 900°.

In this case we found that the attack of sodium carbonate on nickel was too great to permit the use of this metal and we had recourse to a platinum crucible. It was also decided to use a stirrer so that the fused sodium carbonate and the grog could be kept intimately mixed, since the conditions were different from those at 800°, where much of the material remained solid, and stirring was, therefore, out of the question.

The attack at 900° was found to be very rapid; indeed, although the heating period was cut down from three hours to one hour, it was found that all the grog of 16—20-mesh was dissolved within one hour and it was necessary to use material between 8- and 12-mesh if any residue was to be obtained after this period. Difficulties arose, however, during the subsequent separation of this grog and the treatment of the residue with hydrochloric acid. The alumina was dissolved from the grog, but considerable amounts of silica were precipitated, and the separation of this silica from the grog was not satisfactorily accomplished, although various means, both chemical and physical, were adopted in the hope of doing so. Quantitative experiments at 900° were therefore not carried out.

An attempt to obtain measurements by the observation of the time required for the fusion of a given weight of grog also proved to be impracticable.

The general results of the observations with the three alkaline salts, sodium carbonate, potassium carbonate, and sodium sulphate, are set out in Table IV. Experiments were made with four different

TABLE IV.

The Attack of Sodium Carbonate, Potassium Carbonate, and Sodium Sulphate at 800° on Various Fireclays.

Source of clay used.	Grog firing temp.	Per cent. loss in wt. of grog.			Per cent. silica extracted.			Per cent. alumina and iron extracted.		
		Na₂CO₃.	K₂CO₃.	Na₂SO₄.	Na₂CO₃.	K₂CO₃.	Na₂SO₄.	Na₂CO₃.	K₂CO₃.	Na₂SO₄.
Stourbridge	1400°	3·7	12·8	gain 0·01	—	—	—	8·0	9·0	—
	1300	6·8	—	,, 1·64	2·17	—	0·52	—	—	0·52
Halifax	1400	6·98	12·7	0·69	1·45	1·12	0·26	8·46	7·37	0·28
	1300	7·33	14·4	0·42	1·18	1·38	0·30	5·9	8·20	1·02
Ayrshire	1400	15·09	15·10	gain 0·32	1·92	2·46	0·58	12·06	17·4	1·67
	1300	—	—	—	2·17	—	—	—	—	—
Mansfield	1400	5·01	5·63	—	1·01	1·85	—	5·9	6·9	—
	1300	10·52	—	0·28	1·14	—	0·35	7·57	—	0·61

Mean Percentage Volatilisation Loss.

Sodium carbonate .... 1·54
Potassium carbonate .... 5·5
Sodium sulphate .... 0·05

clays fired at each of two different temperatures. The number which indicates the loss in weight sustained by the grog is the mean of several fairly concordant results.

The value to be attached to the quantitative measurements has already been discussed and the figures indicating the amount of silica extracted merely show that this substance probably forms an insoluble silicate in the main, whilst the alumina of the clay produces an aluminate which is readily extractable.

Taking into consideration the comparative losses in weight, the alumina and iron oxide extracted, the loss by volatilisation, and the appearance of the mixture after heating, we may draw the following conclusions :

1. At 800°, sodium and potassium carbonates, sodium and potassium nitrates, and borax, all attack fully burnt fireclay, even although this temperature lies below the melting point of the pure carbonates and borax.

2. At this temperature, the nitrates have a very great corrosive effect, and borax appears to be still more active. Less corrosive, relatively, are sodium and potassium carbonate. The potassium salt in each case is more corrosive than the sodium salt. Sodium sulphate at 800° appears to have only a slight corrosive action as compared with the carbonate or nitrate.

3. The attack on the clay fired at 1,400° is nearly always less than that on the same clay fired only to 1,300°. Hence the advantage in glass furnace practice of using fireclay refractory materials which have been burnt at a high temperature.

4. Ayrshire clay appeared to be the least resistant to attack in each case. Comparison is uncertain in the case of the others, but, in the majority of instances, and particularly where most reliance can be placed on the results, Mansfield clay appeared to be the most resistant, whilst Halifax and Stourbridge clays occupy intermediate positions. Both Ayrshire and Mansfield clays contain a high percentage of alumina. The former does not give a dense body, however, until fired at 1,500° and it may well be that it would then become much more resistant.

5. Rapid increase in the extent of corrosion occurs with increased temperature. Between 800° and 900°, the tests made suggest that the rate of attack increases several-fold.

Although all the above results are of very considerable interest, what appears to us as needing emphasis is the comparatively low temperature at which the alkaline salts, constituting important components of a glass batch mixture, attack fireclay material even after it has been fired thoroughly at as high a temperature as

1,400°.   Extensive attack by the alkaline carbonates, nitrates, and borax at temperatures as low as 800° seemed surprising.   It had, indeed, been shown previously by J. W. Cobb * that sodium carbonate and silica, calcium carbonate and silica, and alumina and silica all show quite distinct evidence of reaction at as low a temperature as 800°.   With sodium carbonate, action was observed even accompanied by the evolution of carbon dioxide at 690°, whilst with alumina, reaction was noted at 720°.   In all these cases, however, there was no evidence of the fusion which we have observed to a very marked extent at 800° in our own experiments.

The influence of temperature on the reaction between fireclay material and alkaline salts has been shown by us qualitatively to be very great.   We had hoped to pursue this subject a little more thoroughly.   Some experiments were, indeed, carried out in which sodium carbonate was filled on alone into a series of small crucibles, the intention being after a specific time to collect and analyse the glass produced and thus to get a measure of the extensiveness of corrosion which could also be correlated with the appearance of the pot.   At comparatively low temperatures, however, that is, at 1,000° and below, the rate of reaction was so considerable that extensive frothing took place, causing the sodium carbonate to pour over the sides, thus making the test impracticable. Attempts were also made to obtain information by suspending slabs of fireclay in a bath of molten sodium carbonate.   The supreme difficulty in this test was to obtain a container capable of resisting for a reasonable period the action of fused sodium carbonate and it appeared to us that nothing short of platinum would serve the purpose.   A sufficiently large container of platinum, however, was beyond our means of acquiring.

The one alkaline salt tested which appears to be an exception to the rapid rate of corrosion at low temperatures is sodium sulphate.   In quite a number of cases at 800° instead of loss in weight, the fireclay grog gained very slightly indicating absorption of this salt.   The result does suggest that possibly neutral salts in themselves have but little action on refractory materials and that it is only when they begin to decompose, yielding alkaline oxides, that marked action begins.   The temperature of decomposition would, in such case, be a more important factor than the melting point, at any rate, in so far as chemical attack was concerned as distinct from the possibility of mere physical solution of the fireclay in the molten salt.   Cobb, whose experiments have already been referred to, found that reaction between sodium

* *J. Soc. Chem. Ind.*, 1910, **29**, 311.

sulphate and silica did not occur until a temperature of 1,120° to 1,130° was reached, and this temperature is in the neighbourhood of the incipient decomposition point of sodium sulphate. The known corrosive action of common salt on refractory materials at temperatures above 800° is possibly to be explained by the influence of the presence of water vapour, which even in the neighbourhood of the melting point of common salt begins to decompose it, with the production of caustic soda and hydrogen chloride. Such a reaction would account for the difference in the temperature at which sodium chloride and sodium sulphate become corrosive.

The above results should warn glass manufacturers of the advisability of adopting all means of preventing any undue segregation of alkaline salts during the melting process. A thorough batch mixing, which by intimate contact between the alkaline salts or other bases and the sand will direct the chemical activity of such salts towards the sand rather than towards the material of the pot, is likely to conduce to this end. It is also very likely that given well-mixed batch, a high melting temperature is better than a lower temperature for this purpose, since slower melting is more likely to lead to segregation of the alkaline salts owing to their becoming fused at an early stage of the founding process.

Summary.

1. Sodium carbonate, potassium carbonate, sodium nitrate, potassium nitrate, and borax all attack well-burnt fireclay extensively even at as low a temperature as 800°.

2. The nitrates are more corrosive than the carbonates, and the potassium salts more active than the sodium salts.

3. Sodium sulphate (salt-cake) at 800° has only a very slight action on burnt clay as compared with the carbonate and nitrate.

4. Rise of temperature between 800° and 900° causes a rapid increase in the rate of corrosion, due to the carbonates and nitrates.

5. Different clays, fired at the same temperature, exercise different degrees of resistance to corrosion by alkali salts. The resistance, however, is not dependent directly on the chemical composition. One aluminous clay was most attacked, whilst a second was least attacked of four clays tested. The corrosion probably depends on the density of the clay body.

6. Fireclay burnt at 1,400° is more resistant to corrosion than when burnt only at 1,300°.

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XIX.—*The Corrosion of Fireclay by Alkali–Lead Oxide Glasses.*

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(Read at the Birmingham Meeting, March 21st, 1923.)

The work recorded in this paper was carried out in the main at
the same time as the investigations communicated in the preceding
paper. Some sections, however, have been added subsequently in
order to make the study a little more complete.

So far as we are aware, no data, such as we have attempted to
get, had previously been published on the corrosion of fireclay by
glasses. While the investigation was in progress, the researches
of C. J. Peddle were made known, and reference was made by him
to the extensiveness of attack on the small crucibles employed.
The opinions expressed by him were in some cases based on
observation of the colour of the glass—a criterion which is only
permissible in a series of glasses in which the constituents are the
same—in some by the appearance of the pot, whilst in a few cases
the alumina and iron oxide absorbed from the pot were determined
by analysis. As the results have a bearing on those recorded in
the preceding paper, and are of interest in connection with our
experiments now described, reference to them may be usefully
made.

In the series of glasses containing soda, the colour due to iron
oxide absorbed from the pot was deeper the greater the amount
of soda present. In the sodium silicate * glasses this increased
colour was accompanied by an increase in the amount of alumina
in the glass, whilst in the soda–lime † glasses, the following analytical
results were published.

Approx. glass composition.	Al_2O_3 and Fe_2O_3 in batch.	Al_2O_3 and Fe_2O_3 in glass.	Increase due to corrosion.
100 SiO_2 40 Na_2O 10 CaO	0·33	1·02	0·69
,, ,, ,, ,, 40 ,, ...	0·29	1·35	1·06
,, ,, 20 ,, 10 ,, ...	0·39	0·36	− 0·03
,, ,, ,, ,, 40 ,, ...	0·31	0·52	0·21

Other instances of increasing depth of colour with increase of
soda content were found with the soda–lead oxide ‡ and soda
barium oxide glasses.§ Increasing the potash in potash–lead oxide
glasses had a similar effect.‖

* This Journal, Trans., 1920, **4**, 16.   † *Ibid.*, 21.   ‡ *Ibid.*, 300
§ *Ibid.*, 1921, **5**, 202.   ‖ *Ibid.*, 1920, **4**, 310.

The potash glasses were found not to be less corrosive than the soda glasses of similar composition.* Glasses containing other bases such as lead oxide and barium oxide were found to become all the more corrosive as the proportion of base was increased. The glasses with 60 per cent. or more of lead oxide were found very corrosive, whilst in melting a soda–barium oxide glass containing 50 per cent. of barium oxide the attack on the pot was such as to yield an additional 3 per cent. of alumina in the glass.

We ourselves have found that in melting a glass containing about 40 per cent. of lime the pot was rapidly eaten away.

Hence, from these results quoted and from our investigations recorded in the preceding paper, it is clear that batches are likely to become more and more corrosive as the content of alkali salts or other bases increases, alkali salts being most vigorous in their action.

The object of the investigation now to be described was, first of all, to compare alkali–lead oxide batches in regard to their action on fireclay ; secondly, to determine to what extent different fireclays resist corrosive action, and, thirdly, to ascertain the influence of a number of factors, such as the relative corrosion caused by batch melting as compared with cullet melting, and the influence of the previous firing of the pot before batch was added.

For the first two sections of the work outlined, small pots were specially made up with the selected clays, but in the third section, which, it appeared to us, did not call for a comparison of the different clays, we utilised small pots such as are constantly in use for experimental work in the Department.

Experimental.

Four clays were selected for use in the first two stages of the work. Two of them, namely, the Halifax and the Stourbridge clay, have been referred to, and their composition has been quoted in the preceding paper. Owing to a shortage of supply of the same sample of Mansfield clay and Ayrshire clay, these were substituted by two others obtained respectively from Kilwinning and Ruabon, and having compositions as shown in Table I.

Both these clays have a fairly considerable content of alumina. Their physical properties and the changes which occur on firing at various temperatures up to 1500° have been described by us in earlier papers.

Small pots were prepared in a press, and in the first specimens

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* This Journal, TRANS., 1920, **4**, 102.

grog was present. It was decided, however, after an examination of the fired pots to discard the use of grog entirely in order that there might be no danger at all of the glass penetrating fine fissures; that is to say, in order that the crucible itself might expose as completely as possible a smooth surface at the outset of the melting period. It was found that such pots could with care be obtained using the raw clay itself and firing the pots very carefully.

TABLE I.

Compositions of Kilwinning and Ruabon Clays.

	Kilwinning.	Ruabon.
SiO_2	49·34	54·25
Al_2O_3	39·13	37·15
Fe_2O_3	5·62	2·88
TiO_2	4·33	1·48
CaO	0·27	0·42
MgO	0·42	0·99
K_2O	0·71	2·83
Na_2O	0·17	trace
Loss on ignition	13·79	10·77

The procedure adopted was first to heat the pots slowly to a temperature of 1,250° and to allow them to cool carefully. These pots were subsequently heated in the small melting furnace for three hours at 1,350°, batch then filled on, and a second filling added after half an hour. The melting operation was conducted at 1,350° for three hours after the second filling and the glass produced was stirred in a definite manner, using fireclay stirrers of the same material as the pot, two stirrings being given, the first one hour after the second filling and the second fifteen minutes before the glass was poured out to form slabs or discs.

The glass so obtained was analysed and by comparison with the calculated composition, it was possible to ascertain to what extent it had gained in alumina and iron oxide content, as a result of the corrosion of the pot. The amount of increase shown by these two oxides was, indeed, taken as a measure of the extensiveness of corrosion.

Variation of the temperature of the furnace was found to exercise a distinct influence on the amount of corrosion, but after various adjustments it was found possible to maintain a temperature of 1,350° in the different experiments constant to within a very few degrees.

Both soda–lead oxide and potash–lead oxide batches were used, the sodium salts of batch I replacing the potassium salts of batch II

in equivalent proportions. These batches contain less lead oxide and more alkali than those used in the manufacture of lead crystal glass table ware.

Table II.

Material.	I.	II.
Sand	504	504
Red lead	224	224
Borax	10	10
Sodium carbonate	144	—
Sodium nitrate	42	—
Potassium carbonate	—	188
Potassium nitrate	—	50

The complete analysis of the glasses melted was only carried out in two cases; fairly complete analysis, however, was done with a number of the glasses, but in a few only the alumina and iron oxide were determined. The detailed results of the analyses are stated in Table III, whilst the essential results showing the increase in the combined alumina and iron oxide content, and other factors making a clear summary of the experiments, are contained in Table IV.

Table III.

Composition of the Glasses Melted.

Type of batch.	Melt No.	SiO_2.	PbO.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.
Potash–lead oxide.	M4	57·81	24·80	0·37	0·09	0·11	0·05	16·97	0·04
	M7	57·48	24·92	0·36	0·07	0·15	0·09		
	M10	57·59	25·43	0·40	0·05	0·13	0·04		
	M11	57·59	25·43	0·42	0·07	0·13	0·09		
	M12	58·28	24·54	0·40	0·08	0·13	0·11		
	M13	58·61	25·27	0·35	0·08	0·19	0·07		
	M14	57·39	24·76	0·46	0·10	0·15	0·06		
	M15	58·34	24·87	0·28	0·06	0·09	0·07		
	M16	58·42	26·13	0·38		0·11	0·07		
	M17	58·10	25·63	0·42	0·08	0·19	0·09		
	M18	57·76	25·40	0·49	0·05	0·22	0·11		
	M19	57·46	26·00	0·32	0·05	0·24	0·13		
Calcd.		58·25	24·68	0·12	0·04	0·02	0·06	16·79	0·05
Soda–lead oxide.	M20	62·58	24·21	0·46	0·13				
	M21	62·86	24·57	0·49	0·11				
	M22	63·01	23·74	0·22	0·08				
	M23	63·28	24·22	0·19	0·08				
	M24			0·39	0·09				
	M25			0·37	0·07				
	M26			0·35	0·07				
	M27			0·33	0·08				
Calcd.				0·13	0·04				

TABLE IV.

Corrosion of Different Fireclays by Soda–Lead Oxide and Potash–Lead Oxide Batches.

Type of batch.	Melt. No.	Clay.	Melting Time.		Increase in Alumina and iron oxide.
	M4	Stourbridge.	3½ hours.		0·30
	M11	,,	,,	,,	0·33
	M7	Halifax	,,	,,	0·27
	M10	,,	,,	,,	0·29
	M15	Kilwinning.	,,	,,	0·18
Potash–lead oxide.	M16	,,	,,	,,	0·22
	M17	Ruabon.	,,	,,	0·34
	M18	,,	,,	,,	0·38
	M12	Stourbridge	6	,,	0·32
	M13	Halifax.	24	,,	0·27
	M14	,,	,,	,,	0·40
	M24	Stourbridge.	3½	,,	0·31
	M25	,,	,,	,,	0·27
	M26	Halifax.	,,	,,	0·25
	M27	,,	,,	,,	0·24
Soda–lead oxide.	M22	Kilwinning.	,,	,,	0·13
	M23	,,	,,	,,	0·10
	M19	Ruabon.	,,	,,	0·21
	M20	,,	,,	,,	0·42
	M21	,,	,,	,,	0·43

The above results appear to indicate three things fairly definitely. The first is that different clays under the conditions of our experiment appear to exercise a different degree of resistance to the action of the melting batch. The results which show this may perhaps be more clearly summarised from the preceding tables in a further table below :

TABLE V.*

Resistance of Different Clays to the Action of Alkali–Lead Oxide Batches.

Batch.		Measured in terms of the alumina and iron oxide extracted. Clay.			
		Ruabon.	Kilwinning.	Stourbridge.	Halifax.
Potash–lead oxide.		0·34	0·18	0·30	0·27
		0·38	0·22	0·33	0·29
	Average :	0·36	0·20	0·32	0·28
Soda–lead oxide.		0·42	0·13	0·31	0·25
		0·43	0·10	0·27	0·24
	Average :	0·42	0·12	0·29	0·24
	Order of resistance in both series.	4	1	3	2
	Percentage porosity (1300°)	11·3	14·0	22·3	25·4

The above results are based on the melting time of three and a half hours in each case.

The results appear to indicate that the pot made from the Kilwinning clay resisted the attack of the melting batch more completely than the others, whilst the Ruabon clay was most extensively corroded. These results apply both to the potash and to the soda glasses. In this connection, the resistance offered does not increase as the porosity diminishes, at any rate, not with the porosity as determined at 1300°. The Kilwinning clay had a comparatively small porosity, but, on the other hand, the Ruabon clay, which was least resistant, had the smallest porosity of all.

The second deduction is that the potash batch was, generally speaking, more corrosive than the soda batch. The results obtained with the Ruabon clay do not bear out this order, but it does hold in the other three cases; and since it has been shown in the preceding paper that potassium carbonate and nitrate attack fireclay more rapidly than the sodium salts, we should expect batches containing these salts to have the same relative corrosive effects. It must be remarked, however, that although present in equivalent proportions in the different glasses, the ordinary weight percentage of potassium oxide in the potash glass is approximately 17 as compared with 13, the percentage of soda in the sodium oxide glasses.

The third point which is of interest is that the corrosive action appears to take place in the earlier stages of the melting operation, that is, before the bases have reacted completely with the silica. This would be a legitimate deduction from the results recorded in the preceding paper. The deduction is confirmed by the small influence which time exerts on the amount of corrosion. Thus it will be noted that after six hours the alumina and iron extracted from the Stourbridge clay was practically identical with that obtained in three and a half hours; and in two experiments with Halifax clay, prolonged for twenty-four hours, whilst in one experiment there was an increase, as compared with the three and a half hour period, of about 33 per cent., in the other no further gain was recorded.

In order, however, to test this point more completely, a series of meltings was carried out to determine the amount of corrosion which the glass itself exerted. This was done by preparing a quantity of the soda–lead oxide glass, reducing it to cullet, and remelting it under the same conditions of experiment.

The Extent of Corrosion produced by Cullet.

In these experiments the pots employed had the same size as those in the preceding experiments, but it was considered sufficient

to use the normal pot made of a mixture of raw clay and grog. The pots were heated at 1350°, maintained for three hours at that temperature, and the soda–lead oxide cullet of known composition filled on in two stages in just the same way as the batch had previously been added. The stirring operations and length of time of melting were precisely as before. Table VI contains the results of the experiments.

TABLE VI.

The Effect of Glass Alone in Corroding Fireclay.
Composition of Glasses Produced from Cullet.

		SiO_2.	PbO.	Al_2O_3.	Fe_2O_3.	Increase in Al_2O_3 plus Fe_2O_3.
Cullet		61·96	25·82	0·22	0·07	
Glasses melted from cullet.	1	63·05	25·02	0·28	0·08	
	2	63·11	25·14	0·28	0·09	0·08
	3	63·06	25·10	0·28	0·09	

Three separate meltings were done and they agreed remarkably well. On comparison of the composition of the cullet and of the remelted glass, it is clear that the increase, due to the corroding action of the glass itself, in the amount of alumina and iron oxide is small, averaging only 0·08 per cent., whilst using batch the increases have been shown to be three or four times as much (compare Table VII, which concerns similar pots containing grog). It is quite clear that the most corrosive period is during the early melting stages, and that it is to the alkali salt constituents of the batch rather than to the glass that corrosion is due.

The Effect of Previous Firing on the Resistance of Pots to Glass Batch.

It appeared to us very desirable to ascertain what advantage there might be gained by firing the pot for a period before charging in the batch. The beneficial effect of such previous firing has been pointed out by several observers,* and we ourselves, in the course of many hundreds of experimental meltings, have made it a matter of practice to fire our small pots of 56 and 100 lb. capacity for at least twenty-four hours at 1,400° after setting in the furnace before filling on the batch, the results of this procedure having been found by us to be very satisfactory.

Some quantitative evidence, however, appeared to be desirable on this point. Accordingly, three series of meltings with soda–lead oxide batches were undertaken. In the first, the pots were raised in the melting furnace to 1,350° and then immediately charged

* See, for example, this Journal, TRANS., 1918, 2, 170, 270, 288.

with batch.   In the second set, a baking of three hours at 1,350° was given before the addition of the charge, whilst in the last series the baking process was extended to twenty-four hours at 1,350° before melting was begun.

The results of these operations are revealed in the partial analyses of the glasses obtained.   The value referred to as calculated is that determined from the batch.

TABLE VII.

Composition of Glasses produced in Heat-treated Pots.

I. *Pots charged at 1,350° without baking.*

	SiO_2.	PbO.	Al_2O_3.	Fe_2O_3.	Increase in total alumina and iron oxide content.
Calcd.	60·98	26·74	0·11	0·02	
1	62·78	26·17	0·35	0·07	0·29
2	62·66	26·83	0·28	0·07	0·22
3	63·22	25·35	0·32	0·06	0·25

II. *Pots baked three hours at 1,350° prior to being charged.*

	SiO_2.	PbO.	Al_2O_3.	Fe_2O_3.	Increase in total alumina and iron oxide content.
Calcd.	60·98	26·74	0·11	0·02	
1	62·62	26·30	0·28	0·05	0·20
2	62·60	26·86	0·26	0·06	0·19
3	62·62	26·50	0·28	0·06	0·21

III. *Pots baked twenty-four hours at 1,350° prior to being charged.*

	SiO_2.	PbO.	Al_2O_3.	Fe_2O_3.	Increase in total alumina and iron oxide content.
Calcd.	60·98	26·74	0·11	0·02	
1	61·76	25·69	0·26	0·04	0·17
2	61·52	25·86	0·22	0·04	0·13
3	61·50	25·69	0·25	0·04	0·16

The foregoing results are perfectly definite and conclusive.   When the pot was not baked the average increase of iron oxide and alumina, that is, the amount of these oxides taken up from the pot, was 0·25.   When baked for three hours prior to charging, the amount was reduced to 0·20, and after baking for twenty-four hours to 0·15.   These results are worthy of the attention of all glass manufacturers, and indicate that substantial benefit is to be obtained not only in a reduction of the corrosion of the pot or block

by firing at a fairly high temperature before batch comes in contact with them, but also the colour of the glass produced is bound to be much improved.

The small pots used naturally presented a relatively greater surface to the action of the batch than is the case on the large scale, but undoubtedly the only difference between the results in commercial melting and those described here is one of relative proportion. The same principles will apply.

The Effect of Spraying the Pot Interior with Soda Ash Prior to Batch Melting.

Discussion has taken place in regard to the influence of alkalies in stimulating the production of a sillimanite layer on clay surfaces when the clay material is fired at high temperature. We have ourselves occasionally found some benefit by spraying the interior of a pot with a very small amount of soda ash and then continuing the firing of the pot for a period before charging. Such an action may be regarded as at least tending to produce a vitreous surface.

It seemed of interest to us to test the effect in this series of experiments on corrosion and accordingly a further series of meltings was carried out in which the pots after being heated at 1,350° were sprayed with a little finely powdered soda ash and then baked for a further three hours before the charge was added.

The compositions of the glasses melted under these conditions are set out in Table VIII.

TABLE VIII.

Composition of Glasses prepared in Pots Sprayed with Soda Ash, Baked Three Hours at 1,350° and then Charged.

	SiO_2.	PbO.	Al_2O_3.	Fe_2O_3.	Increase in total alumina and iron oxide content.
Calcd.	60·98	26·74	0·11	0·02	
1	62·36	24·96	0·31	0·06	0·24
2	62·18	24·91	0·30	0·07	0·24
3	62·70	24·35	0·28	0·07	0·22

The differences in the alumina and iron oxide content are slightly larger than when the pots were baked for three hours without being sprayed. The results of the experiment, therefore, do not favour this method of treatment, and whilst further experiments might be desirable, it would appear that the safest method of treatment is that on which emphasis has been laid in the preceding section, namely, to bake fireclay refractory materials at a high

temperature prior to batch materials being permitted to come into contact with them.

Summary.

Experiments have been made, in small experimental pots, on the corrosive action of soda and potash–lead oxide batches on fireclay at a temperature of 1,350°, the amount of corrosion being measured by the amount of alumina and iron oxide abstracted from the fireclay during the melting process.   The results showed that :

1. Different fireclays resist the action of melted batch to different extents.

2. High alumina content alone does not bestow resistance to corrosion on a fireclay, nor alone does low porosity. Of four clays tested, the least corroded and the most corroded both had a high alumina content and low porosity.

3. Potash glasses are not less corrosive than soda glasses of equivalent alkali content. In our experiments they were found, indeed, to be somewhat more corrosive.

4. The corrosion of fireclay refractory materials occurs most actively during the melting operation, the attack by the glass itself being very much slower than that due to the batch constituents, especially the alkali salts.

5. It was proved that maintaining a pot at a temperature of 1,350° for a period prior to charging in batch increased its resistance materially to attack. Firing for twenty-four hours gave much better results than three hours.

6. Spraying the interior of the pot with a little soda ash and heating it for three hours at 1,350° was not found to possess any advantage in diminishing corrosion.

7. Thorough batch mixing and rapid melting should conduce to diminish the corrosion of fireclay by glass batches.

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XX.—The Effect of Salt-cake in Soda–Lime Batches in Corroding Fireclay Refractory Materials.

By Edith M. Firth, B.Sc., F. W. Hodkin, B.Sc., and Prof. W. E. S. Turner, D.Sc.

(*Read at the Birmingham Meeting, March 21st, 1923.*)

It has been well known in the glass industry that salt-cake, especially when used in tank furnaces, is corrosive of the fireclay blocks with which the furnace is lined. In many instances the corrosion has been due especially to the existence of a floating layer of the salt-cake, and the most severe corrosion was therefore experienced on the flux line blocks, these requiring most frequent repair.

The observation which has been recorded in a previous paper,[*] that in the neighbourhood of 800° or 900° soda ash is much more corrosive than salt-cake, stimulated our interest to test experimentally whether or not at a higher temperature, especially when thoroughly mixed with the batch, salt-cake has the corrosive effect which has usually been attributed to it.

In a slight measure, the reply has already been given and recorded in a paper by A. Cousen and W. E. S. Turner [†] in connection with the production of colourless glass in tank furnaces. It was found in that connection that on the addition of even very small amounts of salt-cake a larger amount of selenium was needed, than when wholly soda ash batches were used to bring about decolorising, and one of the reasons for this necessary increase was the higher proportion of iron oxide found in the glass when prepared from salt-cake-containing batches.

The results of these experiments may be summarised very simply in Table I. This table records the results of forty-two meltings in the same kind of crucible of the same kind of batch under definite conditions as stated in the table. The standard batch was 1,000 sand, 370 soda ash, 200 limespar, increasing amounts of the soda ash being replaced by their equivalent of salt-cake.

It will be seen that at the melting temperature of 1,380° there were three glasses containing a certain amount of salt-cake which contained a smaller amount of iron oxide even than those derived from the purely soda ash glasses. By far the greater number, however, of the salt-cake glasses contained a very distinctly larger amount of iron oxide than those produced from soda ash.

[*] Donald Turner and W. E. S. Turner, this Journal, Trans., 1923, **7**, 207.
[†] This Journal, Trans., 1922, **6**, 168.

Table I.

Iron Oxide in Glasses prepared from Batches containing increasing Amounts of Salt-cake.

A. *Glasses Melted at* 1,380°.

Parts of salt-cake per 1000 of sand.	No. of glasses prepared.	Range of Fe_2O_3 found.
0·0	6	0·06 — 0·08 per cent.
13·5 — 54	3	0·04
13·5 — 54	9	0·06 — 0·09
13·5 — 54	16	0·10 — 0·15

B. *Glasses Melted at* 1,400°.

0	2	0·08 — 0·09
13·5 — 54	9	0·12 — 0·22

The data given in the paper referred to and quoted above leave no doubt that the presence of salt-cake in small amounts did bring about a slight increase in the iron oxide present, this impurity arising as the result of the greater corrosion of the pot.

It seemed to us desirable, however, that measurements should be extended to the case of batches containing quite considerable amounts of salt-cake and even to such as contained this material as the sole source of the alkaline oxide in glass.

Accordingly, a series of glass batches was prepared in which the soda ash was gradually replaced by its equivalent of salt-cake, and from them glasses were melted. The batches themselves are stated in Table II.

Table II.

Corrosion of Fireclay Refractory Material by Salt-cake Glass.

Table of Batch Compositions.

	Sand.	Soda ash.	Limespar.	Salt-cake.	Coke.
A	1000	380	200	—	—
B	1000	375	200	6·7	—
C	1000	370	200	13·4	—
D	1000	360	200	26·8	1
E	1000	330	200	67·0	2
F	1000	280	200	134	5
G	1000	180	200	268	10
H	1000	80	200	402	16
J	1000	—	200	509	20

In order to avoid, if possible, floating salt-cake, a proportion of ground coke necessary to bring about reduction was added in each case except the two with least saltcake, and it was found during the melting operations that when the pot was opened up for stirring, one hour after the second charge had been added, no salt-cake was visible and there was no sign that any segregation had occurred.

In carrying out the experiments, small crucibles were employed, each melting being made in triplicate, the three pots being set in the same furnace so as to ensure as far as possible similarity of furnace conditions. How successful we were in fulfilling this object will be recognised from the very closely agreeing analytical results tabulated in Table III. No lids were used on the crucibles.

The pots were raised to a temperature of 1,250°, maintained at that value for two hours, raised to 1,350° in half an hour, and the first charge of batch then filled on as soon as the temperature of 1,350° had been attained. A second charge was added after half an hour interval. The glass was stirred after a further hour and a second time after the lapse of two and three-quarter hours from the

TABLE III.

Composition of the Glasses.

	SiO_2	Al_2O_3	Fe_2O_3	SO_3	CaO & MgO	Na_2O
A (Calcn.)	75·39	0·13	0·02		8·08	16·37
Expt. 1	76·20	0·25	0·11	0·03		
,, 2	76·18	0·24	0·10	0·04		
,, 3	75·80	0·28	0·10	0·01		
B (Calcn.)	75·39	0·13	0·02		8·08	16·38
Expt. 1	76·64	0·27	0·10	0·37		
,, 2	75·46	0·26	0·10	0·37		
,, 3	75·70	0·28	0·11	0·36		
C (Calcn.)	75·39	0·13	0·02		8·08	16·38
Expt. 1	75·69	0·28	0·12	0·29		
,, 2	75·70	0·30	0·13	0·29		
,, 3	76·06	0·33	0·13	0·24		
D (Calcn.)	75·37	0·13	0·02		8·08	16·39
Expt. 1	76·68	0·40	0·11	0·61		
,, 2	75·56	0·46	0·12	0·54		
,, 3	75·34	0·47	0·13	0·64		
E (Calcn.)	75·37	0·13	0·02		8·08	16·42
Expt. 1	75·08	0·59	0·11	0·79		
,, 2	74·68	0·50	0·11	0·74		
,, 3	75·28	0·68	0·14	0·65		
F (Calcn.)	75·34	0·13	0·02		8·08	16·44
Expt. 1	75·66	0·48	0·16	0·47		
,, 2	75·70	0·48	0·14	0·45		
,, 3	76·16	0·51	0·15	0·48		
G (Calcn.)	75·28	0·13	0·02		8·07	16·50
Expt. 1	75·78	0·90	0·16	0·45		
,, 2	76·46	0·94	0·18	0·43		
,, 3	76·24	1·02	0·16	0·38		
H (Calcn.)	75·23	0·13	0·02		8·06	16·57
Expt. 1	74·56	0·85	0·17	0·45		
,, 2	75·52	0·92	0·16	0·40		
,, 3	75·30	0·84	0·16	0·38		
J (Calcn.)	75·16	0·13	0·02		8·06	16·61
Expt. 1	74·94	1·13	0·17	0·38		
,, 2	75·37	1·12	0·20	0·40		
,, 3	76·06	1·20	0·22	0·41		

addition of the second charge. After three hours the glass was poured.

The temperatures of 1,250° and 1,350° were selected as probably approximating to commercial conditions, as comparatively few manufacturers yet fire their tank furnaces or their pots for many hours at 1,350° or 1,400° before a charge is added.

Analysis of each sample of glass was then made in order to ensure first of all that corresponding glasses resulted and that the conditions for comparison therefore existed ; and, secondly, in order to determine from the increase in the amount of alumina and iron oxide the extensiveness of corrosion. This method followed closely that already adopted in the preceding papers dealing with lead-containing glasses. It was not thought essential to determine the amount of lime or of the alkaline oxide present, the other figures being sufficient for the purpose of the experiment.

Table III sets out the results of our tests.

It may be noted that the amount of magnesia present varied from a trace to only 0·04 per cent., and consequently has not been recorded separately.

Generally speaking, there is good agreement between the results of the three determinations in each set with the same type of batch.

For the purpose of reviewing the extensiveness of corrosion, a further table (Table IV) has been drawn up. In this table the amounts of alumina and iron oxide have been added, and the amount of these oxides present in the batch materials has been subtracted. The difference which is recorded, therefore, corresponds with the increase as the result of the corrosion of the pot. In order to simplify the table, an average has been taken of the three results in each set.

TABLE IV.

	Parts of salt-cake per 1000 of sand.	Average increase of Al_2O_3 and Fe_2O_3 in glass.	Average per cent. SO_3 in glass.
A	0·0	0·18	0·03
B	6·7	0·22	0·37
C	13·4	0·28	0·27
D	26·8	0·43	0·60
E	67·0	0·56	0·72
F	134·0	0·49	0·47
G	268·0	0·97	0·42
H	402·0	0·88	0·41
J	509·0	1·29	0·40

These results do not show a perfectly continuous increase in the amount of alumina and iron oxide, but the slight discrepancies may

possibly be ascribed to a very slight temperature fluctuation, or possibly to slight differences in the condition of the different pots. Considering the results as a whole, however, the conclusion to be drawn is never in doubt. There is a definite and notable increase in the extensiveness of corrosion with the increase in the salt-cake present, the amount of the iron oxide and alumina taken during the fusion of the all-salt-cake batch being seven times greater than that from melting the all-soda ash.

It is of interest to note that observation of the pots themselves before any analysis was made was quite in agreement with the subsequent results of analysis. The part of the pot most affected was the line of contact between the glass and the pot itself. At this level the ring, or rather band, which was observed became deeper as the amount of salt-cake was increased.

It seemed to be of interest to test whether or not the amount of corrosion had any connection with the proportion of sulphate or salt-cake left undecomposed in the glass, and although the glasses were not completely analysed this special constituent, namely, SO_3, was determined.

It will be seen from the table that there appears to be no connection between the SO_3 content of the final glass and the extensiveness of corrosion. The latter depends almost certainly on the action of the batch during its course of melting and not on the resulting glass. It would be of interest to ascertain to what extent the degree of corrosion varies with the temperature of the furnace, and when the opportunity permits we propose to carry out this test.

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DISCUSSION.

MR. E. A. COAD-PRYOR said he assumed there was no intention on the part of the authors to claim that any one of the clays tested was better for the pot-maker than another ; for there were obviously a number of other factors bearing on this point.

It would be rather interesting to know whether, in these particular experiments, the porosity was roughly proportional to the attack. From one of the figures shown on the slide he gathered that it was not. He was very much interested in the test of spraying the pot with soda ash. It was specially interesting because there was reason to suppose, as Prof. Turner had hinted, that the reverse, in certain circumstances, would be expected to happen. There did not appear to be any doubt that when refractories were in

contact with glass something happened which made the refractory a good deal more insoluble in the glass. Possibly, in the spraying test, a little too much soda ash had been sprayed on. Or possibly by the volatilisation of the silica there might have been a stiffening up of the refractory. One noticed this particularly in tank furnaces, where the refractory material never got anything like so hot as in the experiments which had been described. He had brought with him two samples of tank blocks which had recently been taken from a tank furnace. One was of a texture to produce this stiffening, and the other of a very similar composition, but of a different texture, which did not show such vitrification in use. This difference was rather interesting, because, in the case of a tank block, the furnace was cooled from the outside, and therefore never really got very hot. This block had worn like stone, whilst the other had worn away quickly. In the light of these observations, it struck him as rather curious that the spraying test had failed to cause improvement.

It was also mentioned in the paper that there was practically no corrosion of the pot after the batch had once melted down.

It would be interesting to know whether the authors had ever tried, or contemplated trying, another melt in the same pot, or glazing the pot before the experiments were started. Incidentally, he would also like to know if there was any grog in the pots.

The last result of the salt-cake series of experiments was both interesting and surprising. One would have expected, of course, from the observation of melting conditions, that the small amount of salt-cake would have had a beneficial effect, but one would like to know whether the experimenters noticed in the pots any corrosion along the flux line, which would be more indicative of salt-cake being on the top than any observations described.

Mr. W. F. Pearson asked if the authors could say what would be the effect on the corrosion of blocks having a larger percentage of sodium chloride in the salt-cake.

Dr. R. D. Bain : In the first paper attention had been directed to the rather large corrosive effect of the materials from the batch at the low temperature of 800°, and amongst one of the sets of figures the relative corroding effects of sodium nitrate was mentioned as 42, and potash 61, whilst at the same temperature salt-cake had practically no corrosive action. He rather imagined that in tank furnaces when feeding on a batch, the latter must pass through the temperature of 800° in order to get up to the melting point of 1,300° or so. Secondly, for a rather long period, the batch remained at 800° or thereabouts. The corrosive action of the other materials then was considerably greater than that of salt-cake.

It would almost appear that the corrosive action of the other ingredients of the batch was greater over the whole range than the total corrosive action of salt-cake in the later stages.

MR. E. A. COAD-PRYOR asked if it was possible that the viscosity of the glass might have some effect on the problem of corrosion.

MR. G. V. EVERS : " In connection with the corrosive action of salt-cake, nothing had been said as to the composition of the block. Was that available ? "

PROF. TURNER : " Yes."

MR. G. V. EVERS said he would like to ask the authors what difference they would expect in the behaviour of the blocks if there had been a considerable addition of silica to the clay in preparing the block.

COL. S. C. HALSE asked if Prof. Turner could add some remarks to the paper when published on the action of glass on refractories as contrasted with the batch materials themselves. He had recently had to do with a tank in which extensive corrosion of the side blocks had occurred to a very considerable depth, whilst very great action on the bottom of the tank was also perfectly obvious when the tank was emptied.

DR. CRONSHAW : The papers had been very interesting from the chemical point of view, but he thought they would be of additional interest if Prof. Turner could give some further information as to the physical properties of the refractory materials tested—the porosities of the materials, their permeability, the particular methods of working the pots, and the physical state of the glass. The knowledge of the viscosity of the glass at various stages during the experiments would also be useful in this connection.

PROF. W. E. S. TURNER, in reply, said he would endeavour to take the questions, as far as possible, in order.

Replying to Mr. Coad-Pryor's question concerning the porosities, the corrosive action was not proportional to the porosity of the clay. There appeared to be three or four factors in operation, and none of these factors seemed to be dominant. A description of the clays would be embodied in the text of the paper, but it might be said that the clays tested were those the physical properties of which had been investigated at Sheffield and the results already published of the shrinkage, porosity and so on, up to quite high temperatures. With regard to the action of soda ash sprayed on the pot, there was no doubt of the negative value of the treatment in these particular experiments. In several cases, however, particularly in the preparation of boric oxide glasses, during which extensive corrosion occurred, they had tried various methods of

reducing it, and spraying with soda ash had appeared of advantage in one or two cases.   Therefore, they were in some way surprised at the negative result in this particular case.   Additional tests might be usefully carried out.

The samples which Mr. Coad-Pryor had exhibited were certainly interesting from the point of view of the difference in density, despite the low temperature to which they had been subjected.

With regard to Mr. Coad-Pryor's suggestion to test the corrosion after the pot had already been used once and was therefore well glazed, or to glaze a pot first before melting, this should in due course be done.

In reference to the question of the amount of grog in the pots, full details would appear in the paper.   Some of the pots were specially prepared without grog; others contained 25 per cent.

The test of repeating a melting in the same pot, as suggested by Mr. Coad-Pryor, might certainly be tried with advantage; but he thought the test which had been done was fairly conclusive, namely, the test over the twenty-four hour period, during which there was practically no increase of attack as compared with the three and a half hour period.

With regard to the question as to whether there was any corrosion at the flux line when salt-cake was used, he would say, yes, quite definitely.   In fact, although they went to the extent of carrying out these analyses, they could have stated the order of corrosion by an examination of the pot.   He would not say that a ring was formed at the surface, but there was at any rate a very broad band of depression, the depth of which increased as the amount of salt-cake increased.   He would not, however, agree that this effect was due to floating salt-cake.   In the very early stages, of course, they could not be absolutely certain that none came to the surface.   The pots were, however, closely watched, and the observer at no stage had any evidence of salt-cake coming to the surface.   He thought there might be causes for this flux-line attack other than those associated with floating salt-cake.   He considered Mr. Coad-Pryor himself in work on corrosion had pointed to one cause, namely, the presence of convection currents.   Another possibility was something similar to what he (Prof. Turner) had himself noticed during autoclave tests on chemical glassware. Several times extensive corrosion at the wind and water level was observed, and in one case the ring passed round not only the inside of a flask, but there was a corresponding ring on the outside of the flask corresponding with the water level inside—an extraordinary phenomenon, the reason of which he was not quite clear about.   He would not, therefore, be inclined to think that the

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extensive corrosion of the salt-cake batch at the flux line was necessarily due to floating salt-cake.

With regard to Mr. Pearson's question on the effect of sodium chloride in salt-cake on fireclay blocks, fortunately one did not often meet with this to any great extent nowadays. He had no doubt at all that, like the effect of salt-cake on the surface, so also sodium chloride was corrosive. It certainly had been shown by Cobb that sodium chloride did act on fireclay, forming a definite silicate, containing sodium oxide, alumina and silica. The action was slow at low temperatures, but probably at glass furnace temperatures it was extensive, especially in the presence of moisture.

Dr. Bain suggested that as the batch had all necessarily to pass through a temperature of 800°, at which point soda ash was more reactive than salt-cake, possibly the total corrosion was more due to soda ash than to salt-cake. He (Prof. Turner) thought that the results were perfectly clear in showing that when a soda ash batch and one containing salt-cake but otherwise of precisely corresponding composition were melted under precisely the same conditions, the soda ash batch was always much less corrosive. In each experiment the total corrosion was determined.

In the case of charging into a tank furnace a good deal of the batch did not come into contact with the blocks, although some of it did.

With regard to the viscosity of the respective glasses, a point raised by Dr. Cronshaw, their experience had always been that that of the sulphate-containing glass was higher than the viscosity of the soda ash glass, and for that reason one would rather expect the attack to be somewhat less, rather than greater. General results, which were known, indicated in many cases—although this was by no means certain—that the greater the mobility of the glass the greater was the attack. Certainly extensive corrosion was met with in the case of lithium glasses, in which the viscosity was much less than in soda or potash glasses.

Mr. Evers had asked about the compositions of the clays. These were all available and they would appear in the text of the paper. They were not able to draw the conclusion that an aluminous clay was better than a siliceous clay. One of the aluminous clays was least corroded, but in another case, where the corrosion was extensive, that clay was also aluminous. It was quite likely that the relative order of resistance varied with the temperature of previous firing.

As to the effect of silica, so far as general solubility was concerned, he would be rather inclined to speak with some diffidence

on the point as to whether, if the silica were better distributed through the mass of the clay, the corrosion (or solubility) would be less than if the silica were present in larger portions. The portions exposed might dissolve out, whereas if the silica were distributed uniformly one would expect the solubility to be more uniform and regular. He would like to hear opinions on this matter based on experience.

With regard to the effect of the flow of glass on corrosion, especially round the top blocks, this had been well known by many glass manufacturers during the past three or four years. The flow of the glass, as well as the chemical corrosion, was an active factor in the destruction of tank-blocks, especially if they showed any tendency to be of a spongy character, that is, if the porosity was rather high. The top course was naturally the seat of a more active chemical action in the melting of the batch, and he thought it should occasion no surprise that the top blocks should wear thin. What had been rather astonishing was the fact that at one or two factories it had not been the top course of blocks, but the second course, which had suffered the more extensively.

Turning to the remainder of Col. Halse's question, he thought 3 ft. 9 in. was reasonably deep even for a pale metal tank. The temperature at 3 ft. 9 in. deep should not, he imagined, be excessive, and certainly the amount of glass taken out—50 tons per week—was not particularly great. It was therefore astonishing to find the bottom going so rapidly. He would hesitate to express any opinion other than the fact that there was possibly a distinct current of glass along the bottom of the tank; or that the porosity of the binder blocks put in was rather high.

It was rather interesting to hear that at the working end, where the temperature would probably be some hundreds of degrees less, the binders were intact.

Any further questions on the subject which might be sent in, or any to which he had omitted to reply, he would be pleased to attempt to answer, if members would submit them in writing. He would also be glad if any glass manufacturers or technical workers would care to amplify any of the points with which he had endeavoured to deal, as he felt that on several matters further information might be obtainable from day to day factory observations.

XXI.—*The Drying Out and Warming Up of Tank Furnaces.*

By C. SAXTON, A.M.I.E.E.

THIS operation, which at first sight appears quite a simple and ordinary matter, is really of great importance and deserves to have more attention paid to it than is usually the case in the majority of glass factories.

The object of this preliminary " warming up " of a tank furnace is really threefold.

(*a*) To drive off any moisture that may have collected in the flues, and to dry out thoroughly any new material of construction.

(*b*) To raise the temperature of all the brickwork slowly and regularly, so that the expansion which this increase in temperature entails may be gradual and the effects controlled.

(*c*) To raise the temperature of all the brickwork with which the gas comes in contact to such a degree that when the gas finally arrives at the outlet of the ports into the tank it is sufficiently hot to ignite immediately without risk of going out or causing an explosion.

In order to achieve these results, the general practice in England at the present time is to build one or more fireplaces at each end of the tank on the working floor level, and to allow the hot gases from these fires to pass into the tank and finally to go by way of the ports and regenerative chambers to the chimney.

This method has in the author's opinion several inherent defects, which include distortion of the crown above the fire inlets due to local heating, and the fact that the interior of the tank itself being hot is no proof that the regenerators are sufficiently hot to ignite the gas.

To avoid crown distortion due to unequal and local heating it seemed to the author that the logical manner was to get the heat into the tank in the normal way, that is, by means of the ports, and to do this the base of the chambers automatically suggest themselves as being the best position for placing the drying fires.

The figure gives the general lay-out of the flues and shows the position of the fires in a tank having a crown span of 26 feet with a rise of only 2 feet 11 inches. At the point marked " A " a 9-inch square hole was made in the firebrick stopping, to the end of the flue under the " bearers," and at " B " a similar hole was made in the side of each flue just outside the chambers. The fires themselves were quite small affairs, having a grate approximately 2 feet long

by 12 inches wide, and the height about 12 inches. The air and gas inlet valves were closed, the reversing valves placed in the neutral position and the chimney valves closed.

There were two expansion joints in the crown of the tank and these were covered with loose bricks in the usual way, one brick being removed from each joint at each side to serve as the outlet for the gases from the fires.
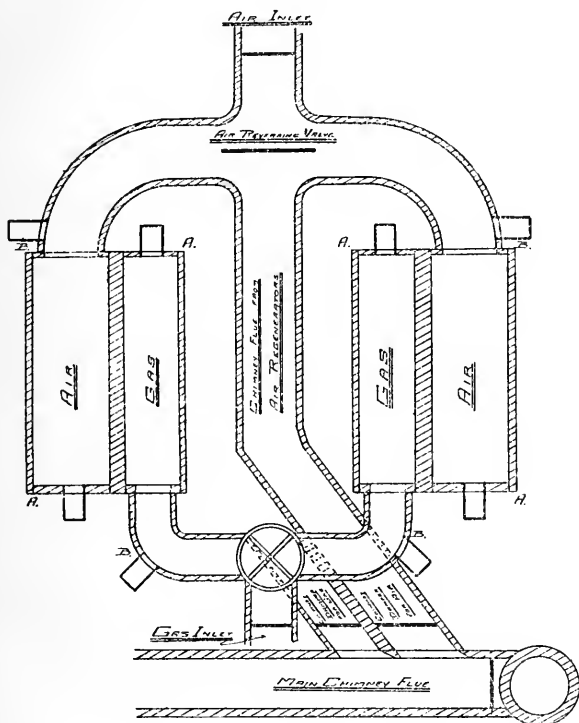
To avoid deformation of the crown due to expansion as the temperature rises, it is obviously necessary that the tension in the tie-rods must be correctly and systematically regulated, and to do this the movement of the crown must be measured.

The method which the author advocates is to employ three steel piano wires tightly stretched about 6 inches above and longtitudinally with the crown, one along the centre and one along each haunch, the wires being attached to $\frac{3}{4}$-inch rods passed through holes in the end buckstays. These wires served as a fixed datum from which measurements were taken down to the crown, at frequent intervals along its length. It was thus possible to get a perfect

knowledge of any movement, which could be controlled or counteracted by tightening or slackening the necessary tie-rods.

Each stack or burner of the furnace was provided with a slide or damper in both the gas and air channels, so that although they were not placed there for this reason it was possible to obtain very easy regulation of the heat distribution in the tank.

The object of the dampers was originally to facilitate any repairs that might be necessary to the burners or stacks whilst the tank was in operation, and they quite paid for the slight extra cost of construction. The dampers in the two outside stacks were also occasionally useful from the point of view of control of the temperature whilst working and undoubtedly led to a saving in fuel.

It will be noticed from the diagram that there are separate chimney dampers for the air and gas chambers, and this is a feature which possesses undoubted advantages, in that the diversion of the waste gases between the gas and air chambers is under control, and if, for example, after the tank has been in operation some time, the gas chambers get somewhat blocked with the result that the waste gases tend to pass out by way of the air chamber, it is possible to increase the chimney draft to the gas without increasing the air, which otherwise would leave the relative conditions the same.

Owing to the fact that the hot gases from the drying fires as described have to pass through all the checkers before reaching the tank, they arrive in the tank at first comparatively cool, but gradually increase in temperature as the chambers get hotter, and therefore the tank and crown are heated gradually and progressively, which is what is desired.

Again, when the tank is hot enough to take " gas " one is absolutely certain that the whole of the other brickwork in the chambers and the ports is at a higher temperature still, and full of the products of combustion, so that gas may be admitted with no more risk of explosion than when the usual half-hourly reversals are made.

It is, of course, essential that the chimney flues and the chimney itself are also " warmed up " in order to ensure the necessary " pull " or draught when the tank is first put into normal operation. To do this the chimney dampers are occasionally lifted slightly in order that a certain amount of the heat passes that way instead of upwards through the chambers.

TALBOT HOUSE, ARUNDEL STREET,
    STRAND, LONDON, W.C. 2.

XXII.—*Notes on the Design of Pot Arches.*

By TH. TEISEN, B.Sc., C.E.

(*Read at the Leeds Meeting, June 20th, 1923.*)

THE name pot arch, or as it is often simply called the " arch," suggests in itself a rather simple structure. The old-fashioned type of pot arch was that. The most imposing part of it was a roof formed as an arch which rested on the side walls, and this is probably how it derived its name. It usually had a door in front with an open fire-box on either side with the fire-bars arranged about half-way up. The flue outlet for the burnt gases was arranged in the opposite back wall near the bottom (Fig. 1).

This arrangement is bound to give certain cold pockets inside the furnace. On the other hand, the ensuing lack of proper heat distribution can be somewhat mitigated by longer soaking, which has a tendency to equalise the temperature. The fire-boxes being open, the fire itself is not under proper control. An experienced fireman, however, will endeavour to overcome this by his method of firing, which is by no means so simple as is commonly assumed. Usually the fire-hole is filled up to the top, leaving just sufficient space for the combustion air to enter.

The temperature to which such an arch can be raised is a very moderate one, especially where high class fuel is not obtainable.

FIG. 1.

The common manner of operation was to use a small fire, leaving plenty of smoke in the arch for a number of days. During the last few days the temperature was increased to the neighbourhood of 1000° and the pot then set in the furnace, the temperature of which, as it was usually fired direct, would also be rather low compared with a modern gas furnace.
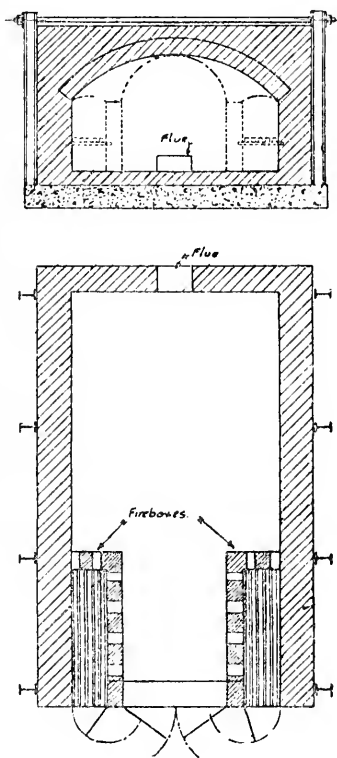
The ordinary continental type of arch was of a somewhat better design, and a typical one is illustrated in Fig. 2, which shows a direct fired furnace (reproduced from Schipman's book *) with a fire-box (*F.B.*) arranged below, combustion flues (*C.F.*) and air flues (*A.F.*) leading to the uptake (*U*) at the back of the chamber, the spent gases passing out through holes in the floor near the front (*D*) and then away to the chimney (*S*).
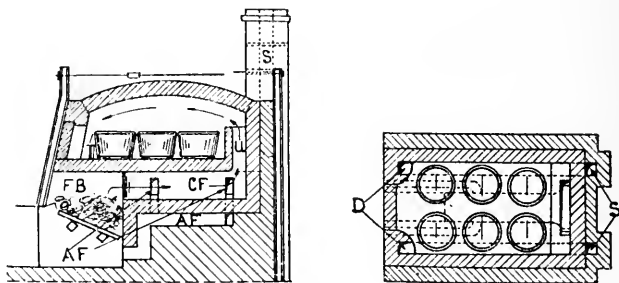
FIG. 2.

From its mode of operation this furnace is of quite good type, but its installation in the glass-house is not so convenient. Fig. 3, taken from the same book, shows a similar furnace connected up to a gas main. This type, however, would scarcely be as hot in the
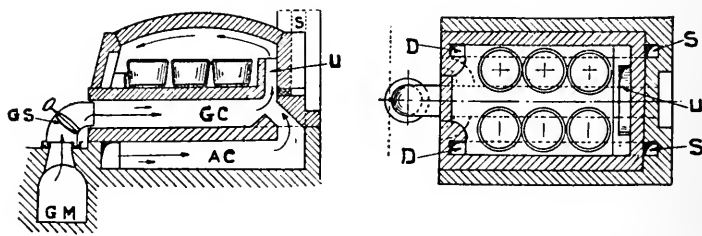
FIG. 3.

bottom as the former and should therefore prove less satisfactory. Whilst these furnace types go a certain way towards obviating the drawback mentioned in the first type described above, and to this extent may be recommended, they are not really handy.

With the entry of the gas-fired pot furnace into the glass industry, however, a demand has undoubtedly arisen for a more modern furnace type for heating pots, a type in which the heat distribution is better and under control and where the temperature obtainable is

* " Aus der Praxis eines Glashüttenfachmannes " (Max Jänecke, Hannover, 1907).

higher, at least 1,200—1,300°. Further, a pot arch of design com-
bining good conditions for working and firing, with easy installation
and economy of space, is called for.

It is interesting in this connection to cite one of the American
Bureau of Standard Papers (1920) on this matter,* which says : " It
is urged that the construction of pot arches be changed to a type
making possible more uniform temperature distribution, as well
as higher temperature.   The down- or up-draft kilns with perforated
bottoms, used extensively in the clay industries, are recommended.
The rate of heating the pot arches should conform to the critical
temperature ranges applying to clay, namely, the expulsion of the
hygroscopic and of the combined water and the oxidation of carbon.
Halts should be made within these ranges until the changes involved
are completed.   Between and beyond the critical temperatures the
heating may be more rapid than prescribed by the present practice."
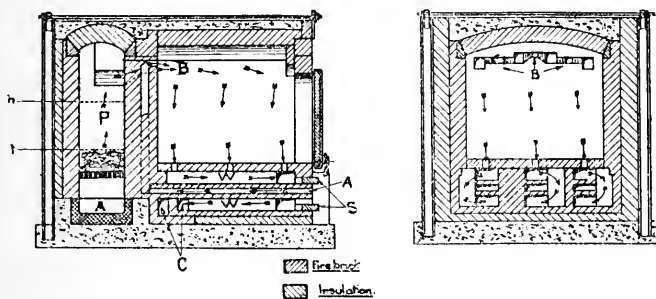
FIG. 4.

The paper in question contains so many other points of interest that
I beg herewith to direct attention to it, and I am only citing the
above concluding remarks because it expresses an opinion which I
had already come to myself.

Some years previously I designed a gas-fired recuperative pot
arch on these lines which met with entire success and was followed
by a number of others.   Fig. 4 shows a standard design on the down
draught principle with the producer arranged at the back of the
chamber.

The letters denote :—P, Producer; A, Ash space; l, Low fire bed ;
h, High fire bed ; B, Burner; W, Waste gas channel ; A, Air channel.
The gases are lighted in what is called a parallel burner where the
intermixing and consequently the combustion of the gas first takes
place in the chamber itself with the result that the flames fill the

* Paper No. 144, " Properties of American Bond Clays and their Use
in Graphite Crucibles and Glass Pots," by A. V. Bleininger.

whole space, completely enveloping the pots. The burning gases are drawn down through holes distributed in the floor under the pots which are placed in the usual manner on bricks, so that the burning gases are actually sweeping the bottom of the pots.

Under the floor tiles the recuperator is arranged consisting of a number of straight air channels, with waste gas channels above and below and separated from these by thin tiles through which the waste heat is transmitted to the secondary air. The feature of this arrangement is its simplicity, and care has been taken to ensure that no leakage occurs by the continuous heating up and cooling down. Pot arches of this design have been working for five to six years, being heated up once or twice a month, without the slightest trouble in any respect.

Fig. 5 shows such a pot arch with open hinged doors in front and the producer fire, ash door, and water supply visible at the side, erected at Messrs. Moncrieff's works at Perth. The chamber is about 6 ft. square.

The general way of working is as follows. During the first stage of burning, a low fire is kept on the grate, fed through the ash door. The secondary air slide is closed and the furnace is in other ways direct fired. It is at this stage a matter of driving out the hygroscopic and later on the combined water without producing surface cracks (crizzles). For that purpose water is kept dripping on the fire-bars as well as on a plate arranged in front of them, thereby producing a certain amount of steam which helps to retard a too quick drying of the surface parts and allows the inside to evaporate its moisture at the same rate as the outside. The pot walls, in other words, sweat the moisture out.

The steam produced makes it unnecessary to run with such a dense smoke as is otherwise usual, since it really serves the same purpose.

As the heating proceeds, the fuel layer is somewhat increased, and some secondary air is admitted to the producer through the fire door or in other manner; at this stage the furnace is semi-gas-fired.

When the inside is at a dull red heat, secondary air from the recuperator can be admitted and the fuel bed slowly increased until it works as a fully gas-fired furnace. (Fuel bed up to h.) It is now fired through a fire door arranged about 3 feet above the grate level. This stage is begun when the hygroscopic moisture is expelled and the burning out of the carbonaceous matters has begun, information about which should be found out beforehand.

So far as the common British pot clays are concerned, the firing shrinkage and physical properties have already been investigated

Fig. 5.

1200°
1100
1000
900
800
700
600
500
400
300
200
100

1ST DAY 2ND DAY 3RD DAY 4TH DAY 5TH DAY 6TH DAY 7TH DAY 8TH DAY 9TH DAY
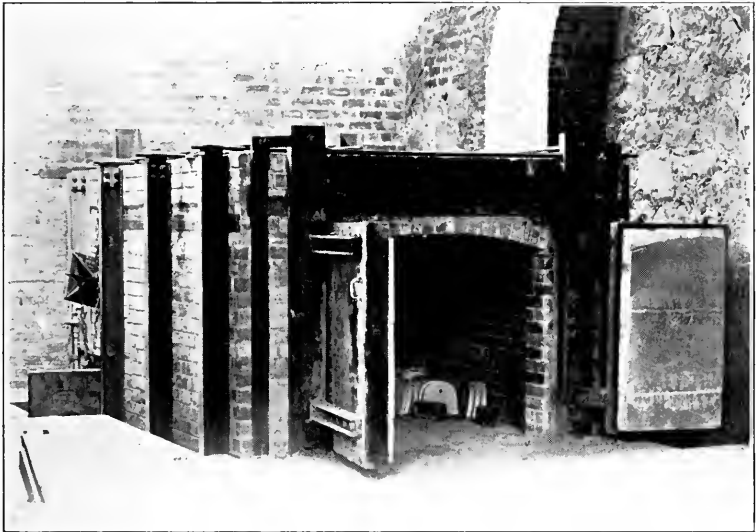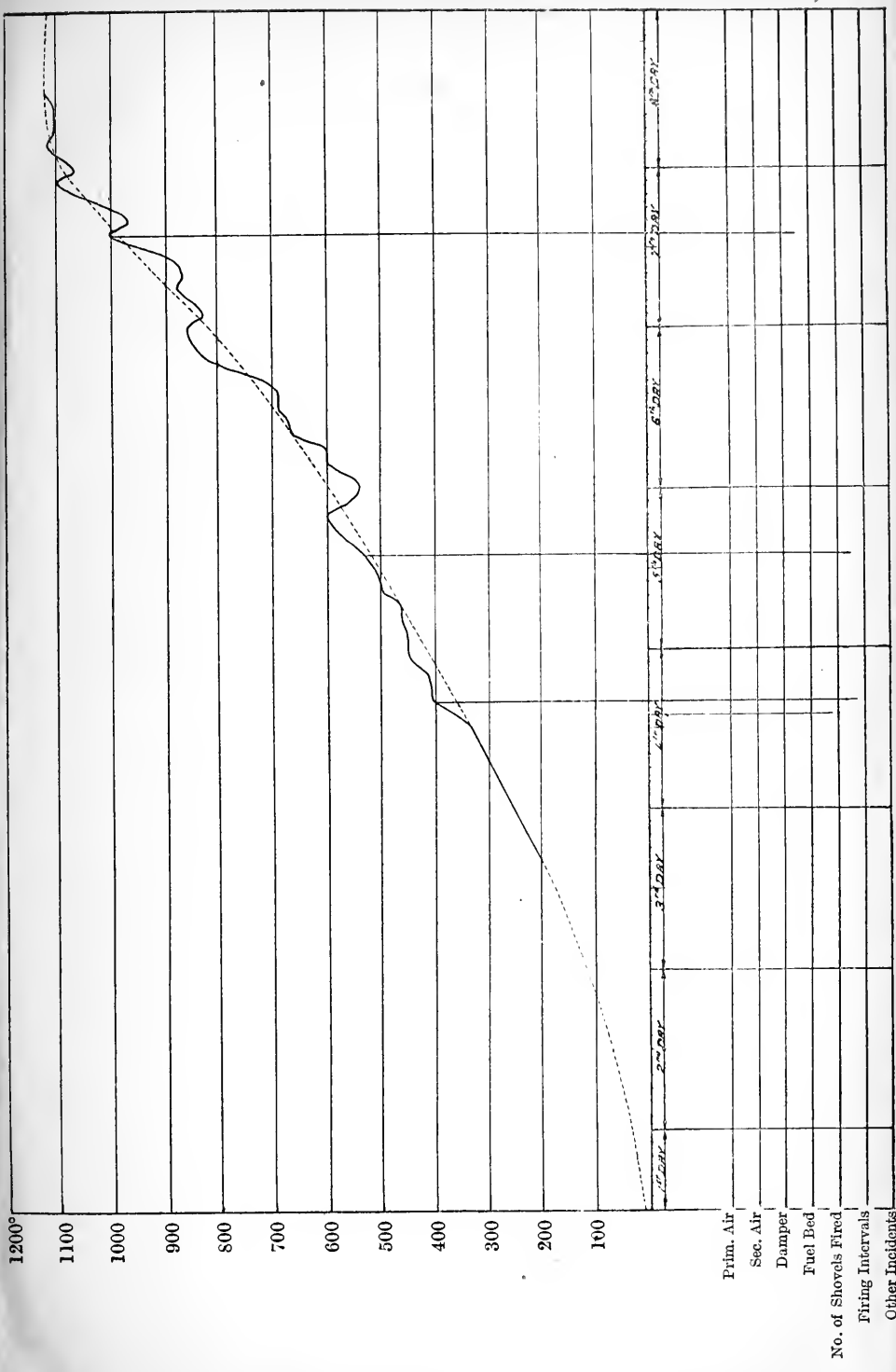
Prim. Air
Sec. Air
Damper
Fuel Bed
No. of Shovels Fired
Firing Intervals
Other Incidents

and reported on by Prof. W. E. S. Turner * and his associates, and this report is of great help in drawing up a new firing programme or improving on an existing one.

It may also be found worth while to follow the suggestion in the Bureau of Standards paper to fire some cubical blocks of the same material and thickness as the pots together with the latter, and at suitable intervals to take one out to ascertain whether the dehydration and carbonisation ranges have been passed. When this is the case, the last stage of burning begins; the temperature is raised above 1,200°, and when the maximum is reached the pots are kept for a time at this temperature before being set.

To indicate in an easy manner the procedure of such a heating period, a curve (Fig. 6) is reproduced giving the temperature as a function of the time taken in the author's type of pot arch. It should be remarked that the temperatures registered are not true temperatures, the actual temperature being considerably higher. Temperatures up to 1,350° have been obtained in pot arches of this design. On account of an opening near the pyrometer, the curve was not quite as regular as it otherwise might have been and it is by no means held to be an ideal or standard one : its only justification in being shown is that it may illustrate a practical way of keeping a firing record. Moreover, from what has been said above, the most suitable heating curve differs for the different clays, and last, but not least, it will have to fit in with the works practice.

The factors which enter here are mainly the age of the green pots, the temperature in the melting furnace in which they have to be set, and so on. Here again, as in nearly all other matters, success is only secured by co-operation of all the parties concerned.

The producer shown might, where local conditions make it desirable, be arranged below instead of being level with the floor, in which case a still better heat distribution might be obtained, but more space would be required. On the other hand, the above type, as it is shown, takes up little space with proportionately less building cost, and appears, from the results obtained in practice, to be quite satisfactory in this respect and easy to operate.

20A, TEMPLE STREET,
   BIRMINGHAM.

DISCUSSION.

MR. F. LAX said he had listened to the paper with interest, but there were some points on which he would like to be enlightened. First there was the question of the number of pots to be heated in

* See this Journal, TRANS., 1920, **4**, 162, and subsequent work.

one pot arch. He did not know how many pots the furnace just shown would hold, and he would also like to know whether Mr. Teisen favoured smaller arches for fewer pots or larger ones for a greater number of pots. It would also interest him to know what the fuel consumption was in relation to the older styles of arches.

Mr. F. F. S. Bryson inquired about the size of the arch in relation to the size of the pots; in other words, what space was allowed between the pots and the walls. Also what was the heating period for the curve shown.

Mr. J. H. Davidson inquired whether this pot arch was easy to control during the beginning and in what manner a gradual heating was obtained from the first period when it was direct fired until later on when it was gas fired. Would there be any sudden increase at this point? From glancing at it, he thought the curve shown rose rather smoothly and that the different stages of burning could have been more pronounced.

Mr. Teisen, in reply to Mr. Lax, said that the arch shown would hold four small open pots or two open and one large covered pot. He preferred not to build the arch too large, as when the first pots were removed the arch then had to be kept going with only one or two pots left in. Much depended on the works practice. On the Continent, for instance, they often set all pots at one time, especially where the old " Butten " furnace was used. There large arches were an advantage. As in this country the practice was to set pots as and when required, it would be better to have smaller arches holding up to three or four small pots or one or two large ones. So far as the fuel consumption is concerned, it is difficult to give exact figures, but roughly speaking it can be reduced about 25 per cent. as compared with old practice, at the same time reaching a higher temperature.

In reply to Mr. Bryson, Mr. Teisen also said from what he had just said he might conclude that the arch was used for different sizes of pots, but if it was built for, say, a single large pot he would allow at least 4—6 inches between the pot and the wall.

The firing curve in question related to a heating period of eight days. The works in question used previously to bring their pots up in fourteen days, whilst he had in smaller arches brought pots up with success in five days. The eight days was chosen as an average figure and had given quite good results. Where there was any question of danger, he would rather allow a day or two more to start with than lose the pots. Later on they could try cutting down the heating period to a safe minimum.

Replying to Mr. Davidson, the point he had raised was very important, and this furnace just secured a very smooth passage from the direct-fired stage to that of the gas-fired. The running was

indeed very simple. To start with, it was fired through the ash door as an ordinary direct-fired furnace, the grate being arranged about midway. The fuel bed was slightly increased as required, and there was therefore no sudden passage between the direct-fired and the gas-fired stages. So far as the curve in question was concerned, he had already pointed out in his paper that it was not an ideal one. It was only shown as an example of a firing record. If Mr. Davidson would study the curve, however, he would see that the temperature was far from rising proportionally. The last stage of burning showed quite a steep rise in temperature as compared with the beginning and middle stages. Unfortunately, the later records, which would have been of more value if properly filled out, were not available. The pots set on this occasion had given quite satisfactory results.

XXIII.—*Natural Sillimanite as a Glass Refractory Material.*

By S. English, M.Sc., A.I.C.

(Read at the London Meeting, May 16th, 1923.)

One of the most fruitful sources of trouble to the glass manufacturer has to do with the refractory materials which come into contact with molten glass. Cases of exceedingly rapid corrosion of tank blocks, leading to bursts even after only a short working life are known to have occurred comparatively frequently in recent years; the presence of fireclay stones in glass is fairly common, and the rapid corrosion of glass-making pots is a matter that frequently troubles some manufacturers. In the making of optical glass, the proportion of good and saleable glass from a melt would be materially increased but for the pot corrosion that takes place, giving rise to cords and striæ. Furnace refractory materials too have sometimes a factor of safety which is distinctly low. These are some of the troubles which glass manufacturers are seldom free from for long periods, and which cause them to sigh for the day when a better refractory material shall appear to replace the existing fireclay. From the research workers' point of view, also, the rapid corrosion of fireclay crucibles makes it exceedingly difficult or even impossible to carry certain pieces of work to their full conclusion; for example, if a glass is required completely free from iron oxide and alumina, one must have recourse to an expensive container such as of platinum.

It is not suggested that the manufacturer of fireclay materials

is responsible for all these troubles and difficulties of the glass-maker. Very often the real trouble lies much deeper, and may be traced to the fact that glass and clay are not chemically neutral towards one another, and that neither of them may be looked on as a definite, fully saturated chemical compound. In both glass and clay there is practically always an excess of some constituent over and above what is required for complete chemical combination, and even if there were not, the compounds which exist in these materials appear to be of a very loose nature, so that interaction or solution readily occurs when they are heated in contact with each other. The importance of this view is emphasised when highly corrosive glasses containing cryolite or fluorspar are melted in ordinary pots; such glasses attack pots very rapidly indeed, and there can be little doubt that the first stage of this rapid disintegration and solution is the combination of fluorine from the batch (or glass) with the silica of the clay. In a somewhat similar way, the alkali oxides of an ordinary glass abstract the excess silica from the surface layers of a glass pot, although this action is soon interrupted at glass-making temperatures by the formation in this modified surface layer of a compact layer of sillimanite which resists further attack by glass-making materials.* This resistance to attack by glass-making materials is due very largely to the fact that sillimanite is a definite fully saturated chemical compound with no uncombined or loosely combined constituents. Further, its compact interlocking structure enables it to resist erosion much better than clay does. Unlike many clays, pure sillimanite does not soften appreciably at temperatures much below its melting point, and since its melting temperature is as high as 1816° †, it may be used safely to much higher temperatures than clays will withstand.

With indications of such marked advantages, there is little wonder that various experimenters have tried to prepare sillimanite artificially.

Desch,‡ Bleininger § and Malinovsky ‖ have each prepared artificial sillimanite, and have found it to be a very refractory material and to be very strong mechanically, but the preparation of an artificial product has during the last few years been rendered unnecessary by the discovery of natural sillimanite of good quality.

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* S. N. Jenkinson, this Journal, TRANS., 1918, **2**, 13.

M. W. Travers, *ibid.*, 1918, **2**, 170; 1920, **4**, 138.

G. V. Wilson, *ibid.*, 1918, **2**, 177.

† E. S. Shepherd, G. A. Rankin and F. E. Wright, *Amer. Journ. Sci.*, 1909, **28**, 301; 1915, **39**, 9.

‡ C. H. Desch. Private communication.

§ A. V. Bleininger, *J. Amer. Cer. Soc.*, 1918, **1**, 697; 1920, **3**, 155.

‖ A. Malinovsky, *ibid.*, 1920, **3**, 40.

A supply of this natural product was obtained with a view to test its suitability as a glass refractory material and determine whether it fulfilled the claims which might be predicted from the properties of the artificially prepared product.   Polished sections under the microscope showed it to consist almost entirely of sillimanite needles (Fig. 1), the whole mass being bound together in a close, fibrous structure, almost identical with that obtained when sillimanite is formed on the surface of a glass pot.   The occurrence of a small proportion of corundum in this material, and the absence of other impurities, indicated that it should have a melting temperature in the neighbourhood of 1,800° (see diagram given by Shepherd, Rankin, and Wright).   These two points both suggest that this natural product should make a good refractory material, but to obtain definite information concerning its suitability as a glass-making refractory it was decided to investigate its behaviour with special reference to points which cause trouble in ordinary glass-making operations.   For this purpose, the following quantitative tests were carried out :

(1) Determination of a suitable working mixture; (2) Measurement of the drying and firing contractions; (3) Determination of the porosity after firing; (4) Measurement of the amount of the corrosion by soda-lime and potash lead-oxide glasses; (5) Measurement of the reversible thermal expansion.

Simultaneously, similar measurements under identical conditions were made on a standard pot clay mixture.

The Preparation of Test Pieces.

Unlike clays, sillimanite when moistened with water does not become plastic in the least, but remains quite sandy, and of course, in such a condition, it is impossible to work it satisfactorily; and even if it could be worked in this condition, on drying it would fall to pieces, being entirely devoid of bonding power.   Several plastic clays were tried as binders, and finally it was decided to investigate in detail the possibility of using a very plastic ball clay to give the sillimanite the necessary plasticity for working properly the bonding power, to hold the material together in drying and the mechanical strength to allow the material to be handled between drying and firing.   Sillimanite and ball clay were each sieved, and the portions passing through a 20-mesh (I.M.M.) sieve were mixed in the following proportions :—

Mixture	A.	100	Sillimanite and	5	ball clay
,,	B.	100	,, ,,	10	,,
,,	C.	100	,, ,,	20	,,

When moistened with water, the mixture A remained very sandy,

and it was impossible to work it satisfactorily. Mixture B was very short, and could not be worked satisfactorily by hand, although good crucibles could be pressed if great care were taken, and special attention given to controlling the amount of water present. Mixture C could be worked by hand, and fairly easily by pressing. In order to test the properties of the sillimanite itself, and as free as possible from admixture, the easier working mixture C was discarded, and mixture B (100 sillimanite and 10 ball clay) was chosen as a standard mixture for further tests. For comparison purposes, a pot clay mixture, consisting of Stourbridge clays and 30 per cent. added grog, ordinarily used in this department for making pots and crucibles, was made into test pieces, and subjected to test alongside the sillimanite, so that the conditions were identical for both and strict comparison was possible.

Drying and Firing Shrinkages.

One of the chief sources of trouble in the preparation for use of clay refractories is the very pronounced contraction which occurs during the drying period and again during the firing up to furnace temperatures. Firth, Hodkin, and Turner,[*] in testing twenty-seven British fireclays, have shown that on being dried from the working consistency, at first slowly in a warm room, and later in a hot air oven at 110°, the contractions varied between 3·31 and 8·60 per cent. of their original length. On firing samples of these same clays to 1,400°, they found that the total percentage contractions varied between 7·17 and 15·44. These measurements were made on clays free from grog; if grog had been added as is the practice in the making of pots and blocks, the shrinkages would have been rather less, but they would still have been very considerable. If shrinkages of this order took place progressively as the temperature was raised, they would still necessitate great care in the drying and firing of clay refractories. In general, however, these contractions are far from regular, taking place more rapidly at some temperatures than at others, thus demanding careful attention if such refractories are to be fired without the development of numerous small cracks due to the excessive shrinkage of the outer layer. Similarly, in the making of blocks which are to be true to size within very narrow limits, this firing contraction is apt to cause trouble.

To compare the drying and firing shrinkages of sillimanite (mixture B) with the standard clay, slabs were prepared in oiled brass

* Edith M. Firth, F. W. Hodkin, and W. E. S. Turner, this Journal, TRANS., 1920, **4**, 162.

moulds and exactly the same procedure followed as was adopted by Firth, Hodkin, and Turner.*

The air-dried slabs were heated in a hot air oven at 110° for twenty-four hours, and heating for another sixteen hours was found to produce no further contraction. After measurement of the shrinkage, the sillimanite and clay slabs were placed side by side in an electric furnace, raised to 1,400°, and maintained at that temperature for four hours.

	Percentage Drying Shrinkage		Percentage Firing Shrinkage	
	(20—110°).	Mean.	(20—1,400°).	Mean.
Clay	3·92		10·40	
Sillimanite B 1	2·07 ⎫	2·15	2·87 ⎫	2·81
Sillimanite B 2	2·25 ⎭		2·75 ⎭	

These results show how very superior sillimanite mixture **B** is to the standard clay, when drying and firing contractions are the basis of comparison. The drying contraction of sillimanite **B** is not much more than one-half the drying contraction of the clay, and when the drying of the sillimanite is complete, further shrinkage on firing is almost non-existent, being only 0·8 per cent. or less. This is what would be expected from a stable chemical compound which is not subject to transformations, and has very probably been formed at a higher temperature than that at present being investigated. The appearance of the burned slabs (Fig. 2) was also indicative of the superior refractoriness of the sillimanite mixture. The slab was pale cream in colour, and had a smooth, compact surface, whereas the clay slab was brown, and showed suggestions of cracks and of slight blistering, indicating that it had been fired practically up to its safe working limit; overfiring would have occurred had it been heated up to 1,500°. Combining these two factors, namely, the abnormally small shrinkage during firing and the smooth, compact surface on the slab fired at 1,400°, it is evident that blocks or pots made of sillimanite B when once dry could be fired hard and without the exercise of nearly so much care as is at present necessary with clay refractories. In the case of well-dried pots, arching could be reduced to a minimum or perhaps dispensed with altogether, and in the case of tanks the drying and warming up would not be the tedious business it is to-day.

Porosity.

The degree of openness of structure of a glass-making refractory material is a matter of great importance, as it determines the ease with which molten glass can penetrate into the body of the material.

* Firth, Hodkin, and Turner, *loc. cit.*

Fig. I.

Magnified 33 diam.

Fig. 2.
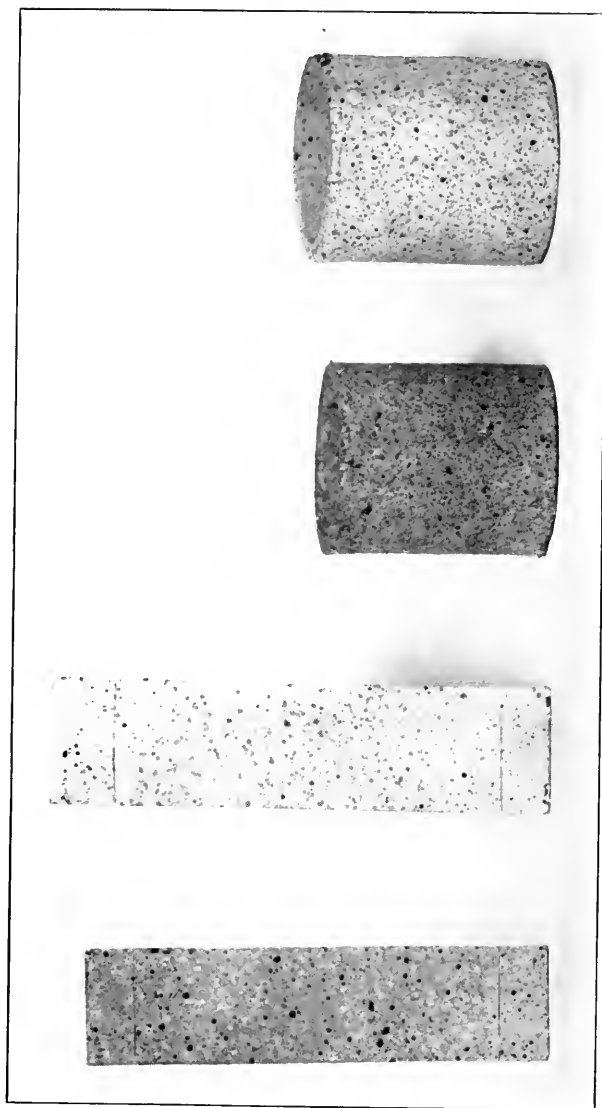
The openness of structure, or porosities of the sillimanite B and clay slabs after firing at 1,400° were determined in exactly the same way as described by Firth, Hodkin, and Turner,* and the results showed that the sillimanite was rather less porous than the clay as set out below.

Porosities after Firing at 1400°.

$$\frac{\text{Vol. pores} \times 100}{\text{Vol. solid material}}.$$

Clay	15·6
Sillimanite B.	13·0

The Corrosion by Molten Glass.

The most common cause of failure in both pots and tank blocks is unexpectedly rapid corrosion due to the interaction of glass-making materials or molten glass itself with the refractory material used as a container, and consequently the most urgently needed improvement in our refractories is an increased resistance to the action of molten or melting glass.   In this respect, sillimanite promises well for reasons which have been mentioned already in connection with the development of a sillimanite layer on suitable refractories in contact with glass.   But to get definite evidence on this point, crucibles were made of the sillimanite B mixture and the standard clay.   They were fired side by side in a gas furnace to a temperature of 1,420°.   After firing the difference in size and general appearance was most marked as shown in the photograph, Fig. 2.

Cullet prepared from two glasses such as are in common use was remelted in these pots for six hours at a temperature of 1,420°. One glass was a simple soda–lime silicate prepared from the batch : Sand 1000, soda ash 325, limespar 228, and as broken cullet it showed only a light pale green colour.   The other glass was a soda–potash–lead oxide silicate made from the batch : Sand 900; red lead 600; potassium carbonate 132·7; soda ash 128·5; potash nitre 48; manganese dioxide 2 ; and as cullet it was also practically colourless. After the prolonged remelting, the soda–lime glass in the sillimanite crucible was still only a pale green, whilst the same glass in the pot clay crucible had a fairly deep green colour.   Similarly, the lead glass remelted in the sillimanite crucible had a very pale yellowish-green colour, whilst in the clay crucible it was a distinctly deeper yellowish-green.   The marked difference in the colours indicated that both glasses had attacked the clay crucibles much more than the silli-manite crucibles, but to obtain a direct measure of this attack,

* Firth, Hodkin, and Turner, *loc. cit.*

the iron oxide and alumina contents of the glasses, both before and after remelting, were determined. These results, together with the increase in iron oxide and alumina contents during remelting, are tabulated below.

Percentage Amounts of Iron Oxide and Alumina present in Glasses.

	Original cullet.	Clay crucible remelt.	Increase.	Sill. B crucible remelt.	Increase.
Soda–lime glass ...	0·48	0·88	0·40	0·62	0·14
Lead glass	0·64	0·98	0·34	0·76	0·12

These figures conclusively prove that glasses such as are ordinarily melted in tanks and in pots attack a well-burned clay crucible much more rapidly than they attack a similar crucible made from the sillimanite mixture B, and indicate, under the conditions of these tests, that the rate of attack is approximately three times as rapid in one case as in the other.

The Thermal Expansion.

J. W. Cobb and H. J. Hodsman * have shown that in general the reversible thermal expansion of pot clays is not regular as the temperature is raised, but in clays previously burned to a temperature of approximately 1,300° a rapid expansion occurs at a temperature of about 575°, and, on cooling through the range 600° to 500°, there is a marked contraction. These rapid rates of expansion and contraction are regarded as due to the silica transformation which occurs in this range of temperature, and they render the heating and cooling of siliceous clay refractory materials through this region very liable to cause cracking. Since sillimanite shows no such polymorphic transformations, there should be no irregular thermal expansion as the temperature is raised, and it should therefore be capable of withstanding fairly rapid heating and cooling without undue risk of cracking. Both Malinovsky and Bleininger noticed that artificially prepared sillimanite appeared to have a negligibly small coefficient of expansion, but accurate measurements do not appear to have been carried out.

In order to obtain data on this point, and at the same time compare the rates of expansion of sillimanite B mixture with the pot clay mixture, a slab of each, previously used for shrinkage tests on firing at 1,400°, was mounted vertically on a fixed support near the middle of a platinum wound electric furnace. In a trial experiment, these slabs were fired to a temperature of 1,425°. In between the two slabs a tube of fused silica was placed as shown in Fig. 3,

* This Journal, TRANS., 1919, **3**, 201; 1921, **5**, 16.

and similar but shorter tubes were placed at the top of the two slabs. The silica tubes extended beyond the tube of the furnace, and passed through two sets of guides so as to keep them in position laterally but to allow them to slide vertically. Small metal caps with countersunk depressions were placed on the ends of the tubes, and in these hollows were rested needle points mounted on the underside of two tables each of which carried a long, light pointer. These pointer-carrying tables were held down on the caps by lead weights hanging between the silica tubes. Thus, any differential expansion between the centre stem and a side stem caused the
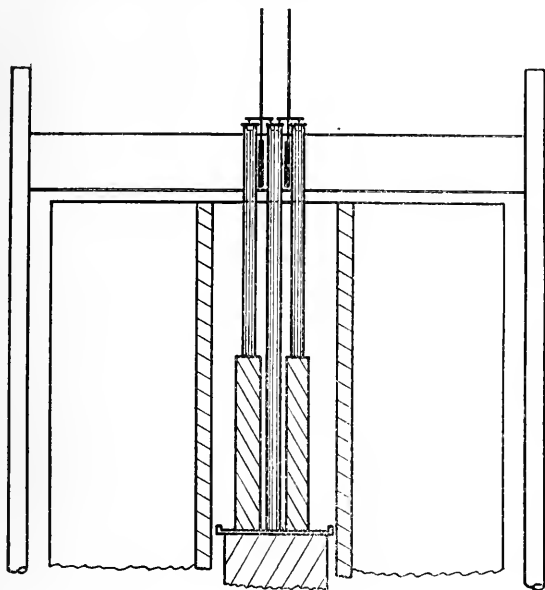
FIG. 3.

corresponding pointer to move to the right or to the left, according to the direction of the relative expansion, and from a measurement of this movement by a travelling microscope any differential expansion could be measured to an accuracy of about 0·0001 cm. For temperature measurements, a Pt–Pt–Rh thermo-couple carefully calibrated to 1,400° was placed in between the two slabs. Readings were taken at about each 200° from the ordinary temperature to temperatures above that at which the silica could be relied on, and before taking each reading the furnace temperature was kept constant near the desired level for half an hour. The temperature was maintained at this level for another quarter of an hour, when the reading was taken again. At temperatures below 1000°, in no case

was there any appreciable difference in any of these pairs of readings, but above 1000°, as might be expected, there appeared to be a small contraction of both the clay and the sillimanite while they were kept at a constant temperature. This small contraction was only apparent, as on cooling to the ordinary temperature and measuring the lengths of the slabs no decrease in length was found, indicating that the gradual variations in the readings was due to an expansion of the hottest part of the central silica stem, which was not compensated by the shorter lengths of silica tubes standing on the two slabs. The expansions (*dl*) of the sillimanite mixture and clay slabs as the temperature was rising are set out below, and plotted in Fig. 4.

Thermal Expansion of Sillimanite and Clay.

Length of sillimanite B slab, 11·1 cm.
    ,,   clay slab,   10·3 cm.

Temperature.	*dl* Sillimanite.	*dl* Clay.
15°	—	—
222	0·0118 cm.	0·0153 cm.
400	0·0236	0·0204
615	0·0363	0·0309
810	0·0472	0·0405
1017	0·0546	0·0495
1185	0·0597	0·0547
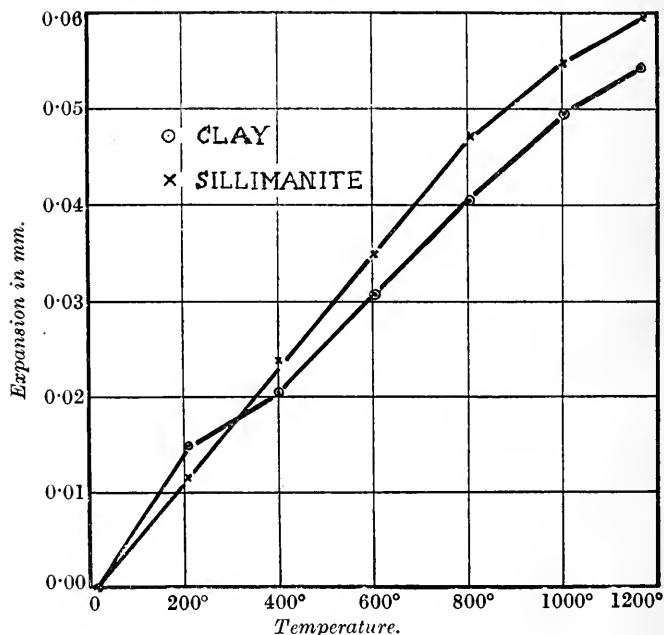
FIG. 4.

From the curves in Fig. 4 it is evident that the sillimanite has a very regular rate of expansion throughout the whole of the range up to 1000°; on cooling over this range it contracts in the same uniform way and at the same rate. The bending in the heating curves between 900° and 1000° is no doubt due to the increased rate of expansion of the silica in this region as was found by Kaye,* who showed that the coefficient of expansion of fused silica was practically constant up to 900° and had an average value of approximately 50×10^{-8}, but in the range between 900° and 1000° the coefficient of expansion rose to 80×10^{-8}. Above 1000°, irregularities were obtained corresponding with the permanent increase in length found in these experiments. Taking the range 15—800°, and assuming an average coefficient of expansion for fused silica of 50×10^{-8}, the coefficients of expansion of the sillimanite and clay are 5.8×10^{-6} and 5.5×10^{-6}, respectively. In this respect, therefore, the hard burned clay and sillimanite mixture are very little different from each other.

Summary and Conclusions.

Natural sillimanite can be satisfactorily bonded so as to form slabs and small crucibles by the use of a comparatively small proportion (9 per cent.) of ball clay.

On drying, this mixture of sillimanite and clay shows a very small shrinkage, and on burning to 1400° it has a negligibly small further contraction.

The porosity of the fired sillimanite mixture is rather less than that of a standard pot clay mixture.

Sillimanite crucibles suffer very much less than do clay crucibles from the attack of glass at high temperatures.

Up to 800°, the coefficient of expansion of the sillimanite mixture after burning at 1,400°, is quite regular, and has a value very close to the mean coefficient of expansion of a hard burned standard clay mixture.

Natural sillimanite should serve as an excellent basis for glass-making refractories, chiefly on account of its high melting point, its very low drying and firing shrinkages, and its marked resistance to corrosion by molten glass.

DEPARTMENT OF GLASS TECHNOLOGY,
    THE UNIVERSITY, SHEFFIELD.

* G. W. C. Kaye, *Phil. Mag.*, 1910, [vi], **20**, 718.

" Natural Sillimanite as a Glass Refractory Material."

By S. ENGLISH, M.SC.

DISCUSSION.

MR. E. A. COAD PRYOR asked if Mr. English would tell them how much grog there was in the clay used in the tests described?

MR. ENGLISH replied that a standard clay mixture was used of which he had not precise knowledge, but thought the percentage of grog was about a third.

MR. E. A. COAD PRYOR said there was one other point, namely, that as regards shrinkage, he was not at all sure some rather mysterious property was not being attributed to sillimanite which it did not really possess. He rather thought the shrinkages were very much what one would expect and, to his mind, it was not the sillimanite which was cutting down the shrinkages. He would like to ask Mr. English whether there were any signs of recrystallisation of the sillimanite, or whether the sillimanite grains preserved their identity during the firing? This was rather an important consideration from the point of view of refractories, because, after all, probably 90 per cent. of the virtue of a refractory material consisted in its texture, and only 10 per cent. was attributable to composition. He would also like to know if Mr. English could tell them what were the relative iron contents of the sillimanite and clay pots respectively.

MR. F. G. FOSTER said he would like to know if the natural sillimanite was available from the newly-found deposits in commercial quantities such as would indicate a reasonably-sustained supply; in what part of the world they had been found; if any particulars were available as to the comparative cost of a glasspot made from sillimanite and of pot clay respectively; and if there were any resultant efficiency factor when the two pots were considered from all points of view, side by side.

MR. C. E. TOWERS asked, if sillimanite was made into blocks what sort of jointing material should be used? In the case of refractory bricks, would not the use of fireclay be impracticable and some other jointing material be required?

MR. F. G. FOSTER : When making blocks which would involve a considerably better jointing material, would it be possible and practicable to face up the blocks with a sillimanite–ballclay com-

pound in such a way that they would not disintegrate, yielding a similar effect to that obtained when sillimanite was formed on the surface of a block or pot when heated in the furnace?

MR. D. TURNER said it seemed to him that the tests carried out had really consisted in employing say 90 per cent. of grog with 10 per cent. of clay. But one had to consider the fibrous structure of sillimanite, and he thought that if the sillimanite were crushed into small grains, or into powdered form, and then mixed with the clay, the advantages of that fibrous structure were lost, and one did not get the same effect as when sillimanite was formed on the surface of a pot in practice. Further, with regard to the tests of melting the glass in the pots, it seemed to him that these were not quite fair tests of corrosion. The sillimanite admittedly contained very little iron, whilst the ordinary fireclay pot, containing, as it did, a much larger amount, got its colour from that fact, without giving any real indication as to the amount of corrosion. He had heard it said that a handful of sillimanite thrown into an ordinary pot of glass dissolved away quite as fast as ordinary clay grog. It seemed to him that unless definite analyses were made of the various mixtures it would not be possible to get any really trust-worthy test as to the amount of corrosion.

MR. W. J. GARDNER said the paper had been a very interesting one, and he had listened to it, from the point of view of the refractory materials manufacturer, with peculiar interest. But it occurred to him that the test was very largely a laboratory one, and one which—although he was open to be corrected—assumed very much that clay crucibles would not give the same result. Whether that might be a fact or not, it was certainly very important to know, from the commercial point of view, what was going to be the cost of this sillimanite when applied practically in works. If they were going to line furnaces with this very wonderful composition, were they going to economise, or was there by any chance something else they might use—compositions such as they could make themselves from materials easily obtainable and at a less cost—which would give the same results? From the laboratory point of view, the tests described were certainly very interesting, but it would be rather more comforting to some of them if they could hear that there was some real chance of being able to apply the new material commercially. The lecturer gave them an example of how the glass absorbed from the clay more colouring matter than it did from the sillimanite. In order to be able to appreciate this point and understand it thoroughly, it would be necessary for them to have a complete set of analyses, because it was quite possible these colorations were brought about by differences of composition.

Therefore, he thought they ought to have the analyses of the various mixtures published along with the paper in due course.

MR. F. F. S. BRYSON : From experiments that had been carried out at the Glass Research Association he could quite corroborate all that Mr. English had said. They had a number of cones made, one of sillimanite and the others of various other types of material, and put them into a pot and fired them. That made of sillimanite was the only one that stood up. With regard to the question of recrystallisation, they found that this did take place. They took a much finer grained sample than that mentioned by Mr. English, namely, 80-mesh and they had great difficulty in getting it to hold up with only a small clay percentage. After firing, they found that recrystallisation had taken place.

MR. G. G. MIDDLETON asked, if this sillimanite was to be made up into large pots what would be their mechanical strength and would they stand up like ordinary clay ? He believed that to be quite an important point. With regard to the corrosion, he believed Mr. English did an alumina analysis, which would be able to corroborate his pot attack figures.

MR. ENGLISH, in reply to Mr. Coad Pryor, said that he was sorry he could not give a definite answer to the question as to whether the sillimanite grains preserved their identity in the fired material, owing to the fact that the paper had been pressed through for that particular meeting instead of being presented a month later. However, there was some evidence that on firing the sillimanite grains lost their identity and that recrystallisation occurred ; the very great mechanical strength of the fired slabs and crucibles was no doubt due to this recrystallisation. Mr. Bryson's contribution to the discussion supported this indirect evidence, and he thought completely answered the question.

The iron oxide contents of the sillimanite, and the pot clay mixture which was used for comparison purposes, were very nearly equal, both being approximately $2\frac{1}{2}$ per cent.

Replying to Mr. Foster, he understood that the quantities of sillimanite obtainable were large, but it was found in somewhat inaccessible districts, which might cause the cost to be rather high. He could not say what the present price was, as he had been fortunate enough to have a supply given to him. The cost-efficiency was, however, a figure one factor of which was directly connected with the results which had been presented. If large size pots and blocks stood up to the action of molten glass as the small crucibles had done, their efficiency would be much greater than that of present-day refractory materials, and although the cost might be three or four times as much, the cost-efficiency would show up in

their favour. With regard to the facing up of clay blocks by sillimanite, he doubted very much whether this could be accomplished satisfactorily, largely owing to the pronounced difference in contraction during firing.

Replying to Mr. Towers, he had not carried out any experiments on jointing materials, but he would imagine that a creamy mixture of finely-ground sillimanite and ball clay in approximately equal proportions would be found to be satisfactory.

In reply to Mr. Turner's remarks concerning the fibrous structure of sillimanite, it was only stated that the fibrous structure existed in the natural material in its bulk form, but since the question had been raised, he suggested that although this fibrous structure was temporarily destroyed during the grinding operations, it would be re-formed, perhaps on a finer scale, during the firing of the slabs or crucibles to 1400° and the recrystallisation which took place at that temperature. Referring to the suggestion that the tests on the corrosion of crucibles by molten glass were not fair, Mr. Turner appeared to be under two misapprehensions; first, that the sillimanite contained very little iron oxide whilst the pot clay contained a comparatively large quantity, whereas the iron oxide contents of the two were approximately the same, as stated in a previous answer. Secondly, the analytical figures which were quoted were for iron oxide and alumina together, and not for iron oxide alone. Since the sillimanite contained much more alumina (as Al_2O_3,SiO_2) than did the pot clay mixture, difference in the balance of the analytical results would be in favour of the clay.

He (Mr. English) agreed with Mr. Gardner, that the tests described were only laboratory ones; he did not pretend they were anything else, but the results obtained in these small-scale tests indicated what might be expected on the commercial scale.

He was glad of Mr. Bryson's corroboration of two most important points, namely, that of the resistance of sillimanite to the corrosive action of molten glass and the recrystallisation after firing to 1400°.

Mr. Middleton's question reminded him of a point he had omitted to deal with, namely, the mechanical strength of the crucibles made from sillimanite. The fired material was exceedingly strong, and not at all brittle. Fired crucibles would withstand very rough usage and were difficult to break. He had thrown one to the ceiling and allowed it to fall on a wood floor. It did not break until the third fall. To test their resistance to thermal shock, he had taken crucibles from a furnace at 1400°, placed them on a cold stone slab to allow them to cool freely, and not one had broken.

"*On the Refractive Index Changes in Optical Glass occasioned by Chilling and Tempering.*"

By F. TWYMAN, F.INST.P., and F. SIMEON, B.SC., F.INST.P.

DISCUSSION.

MR. F. E. LAMPLOUGH (*partly communicated*).—Some of the results of the present research are so surprising and interesting that it would seem very desirable for the work to be continued and confirmed before basing any general conclusions on them.

During the war I had very wide opportunities of realising the effect of variations of treatment as regards moulding and annealing, etc., on the index of optical glass, especially owing to the fact that in the rush of such strenuous times glass had sometimes to be produced in plate form with an expedition which did not permit of good annealing, and some of this glass had later to be re-annealed for the highest class of optical work. Preliminary index measurements of glass direct from the pot were frequently made, and corrected after moulding and annealing.

I had occasion to make very numerous tests of refractive index, using for the determination of indices both the surface and bulk methods of the Pulfrich refractometer and the spectrometer respectively. Such tests showed clearly that bad annealing produced a *general* lowering of index in addition to the variation of index and double refraction. I do not, however, recollect that the index of a moulded plate was ever diminished by fine annealing, and have never had any indication that the operation of moulding by pressure gave a plate of unduly high index. It might be possible for the author to obtain for investigation from the makers of the dense barium crown a sample prism direct from the pot of glass which had not been subjected to the moulding operation.

It does certainly seem desirable that the conclusion drawn in the case of the tempering at the lowest temperature should not rest solely on the result obtained in the third test, and that a longer time should be allowed to elapse before concluding that the maximum index had been attained by tempering at this temperature. Even in the case of the intermediate temperature, the form of the curve would certainly suggest that with more extended temperings the 1·599 index limit would be passed.

It would be very interesting for work of this kind to be supplemented by interferometric observations : larger test-pieces would give better opportunities for these, and make more certain that the results were not vitiated by any changes of a chemical nature.

THE AUTHORS, in reply, said : It is interesting that Mr. Lamplough has not noticed any raising of refractive index by pressure in moulding. We should be interested to hear of another case or of an alternative explanation of the experiments cited.

With regard to the tempering at the intermediate temperature, 520°, experiments were continued for a total time of one hundred and fourteen hours, the final value of 1·5988 being reached in one hundred and one hours, the remaining twelve hours making no difference although measurements were made at intervals of six and a half hours. We concluded from this that the final value had been reached, but we see no reason to doubt the values at the lowest temperature.

An examination of the graph will show Mr. Lamplough that a change of 0·00065 in index was produced in the first half hour, while subsequent treatment for eight and a half hours produced only an additional increase of 0·00005.

XXIV.—*La Méthode Scientifique dans l'Industrie.*

Par Prof. HENRY LE CHATELIER.

(*An Address delivered at the Paris Meeting, July 2nd,* 1923)

J'ai suivi avec le plus grand intérêt le journal de votre société depuis sa création. J'ai pu voir l'importance que vous attachez aux recherches scientifiques et la confiance que vous leur accordez pour le perfectionnement de votre industrie. Vous ne serez donc pas surpris que j'aie choisi pour cette conférence l'étude d'un des points de contact de la Science et de l'industrie.

Rapports de la Science et de l'Industrie.

Le magnifique développement de l'industrie moderne a été la conséquence directe du progrès des sciences, plus particulièrement des sciences expérimentales. C'est là une vérité que tout le monde proclame volontiers aujourd'hui, souvent même sans se rendre compte à quel point elle est profondément exacte. Nous vivons tellement au milieu des applications de la Science que nous finissons par ne plus apercevoir son intervention, comme beaucoup de Parisiens à force de vivre sur les bords de la Seine ne savent plus admirer les magnifiques perspectives qui séduisent le voyageur étranger. Pour bien comprendre le rôle de la Science, il faut, par la pensée, désarticuler l'industrie, de façon à pouvoir en séparer toutes les parties entachées de Science. On s'aperçoit alors, une fois cette

opération faite, qu'il ne reste plus rien.   Enlevez à la métallurgie l'analyse chimique, la mesure des températures élevées, les lois de l'élasticité, et vous retomberez sur la métallurgie des nègres de l'Afrique centrale.   Sans les lois de Ohm, de Faraday et d'Ampère, il n'y a plus d'industrie électrique, et ainsi de suite.   Il n'y a aucun raison de penser que les nouveaux progrès de l'Industrie ne seront pas encore dus, et plus encore peut-être, au concours de la Science. Cette question de l'influence de la Science sur les progrès de l'Industrie mérite donc de retenir l'attention des hommes qui ont comme vous la responsabilité d'affaires importantes.

Examinons d'abord le mécanisme par lequel la Science intervient dans l'industrie.   Il est double : d'une part l'ingénieur utilise à chaque instant les données acquises de la Science ; d'autre part, il peut appliquer les principes de la méthode scientifique aux problèmes innombrables que lui pose journellement la pratique.

Données Acquises.

Les données acquises de la Science sont avant tout les lois générales : lois de Ohm, d'Ampère, servant de base à tous les calculs nécessaires pour la construction des dynamos ; lois de Mariotte et de Gay-Lussac intervenant dans l'étude des machines à vapeur, des moteurs à explosion, des machines frigorifiques ; lois de Lavoisier, fondement de toute la chimie analytique, etc.   La connaissance de ces lois nous donne prise sur le monde matériel, nous permet d'en diriger les phénomènes au mieux de nos intérêts.   Or c'est là tout le but de l'industrie.

En second lieu, la Science met à notre disposition des procédés de mesure indispensables pour régulariser nos fabrications et supprimer les déchets.   On ne songerait pas aujourd'hui à mettre du minerai de fer dans un haut fourneau, sans l'avoir au préalable analysé ; à tremper un arbre de moteur, sans en avoir pris la température ; à mettre en marche un four électrique, sans mesurer l'ampérage. Le remplacement du pouce et de l'œil par des procédés scientifiques de mesure a suffi à lui seul pour transformer bien des industries.

Le savant de laboratoire observe enfin des faits particuliers, dont quelques-uns sont utilisables dans les Arts.   L'observation par Auer de l'éclat de la thorine chauffée dans un bec Bunsen a été le point de départ de l'industrie de l'éclairage par incandescence : la découverte des couleurs d'aniline réalisée dans des laboratoires scientifiques a donné naissance à toute l'industrie des matières colorantes.   Le Néon, l'Hélium et l'Argon trouvés dans l'air par Ramsay ont servi : le premier à l'éclairage par luminescence, le second au gonflement des ballons et le dernier au remplissage des lampes au tungstène.

Sur ce terrain de l'utilisation des données acquises de la Science, nous sommes en bonne posture ; les Universités, les grandes écoles techniques forment dans tous les pays industriels des ingénieurs, des chimistes parfaitement documentés sur l'état actuel de la Science. Mais, objectera-t-on, beaucoup d'ouvriers, de petits patrons travaillent et produisent, c'est-à-dire font acte d'industrie, sans connaître un mot de la Science. Ils suivent, en réalité, l'exemple de M. Jourdain ; ils se servent de la Science sans le savoir. Le petit fabricant de bicyclette met en place des roulements à billes, résultats de longues études sur les propriétés des aciers au chrome et sur les conditions de leur trempe ; il profite de ces recherches scientifiques sans les connaître. De même le petit entrepreneur, qui emploie des fers à T, ignore la raison de leur forme bizarre. Il ne connaît rien aux moments d'inertie et s'en rapporte pour les choix des dimensions aux tableaux de son memento ; des savants ont fait pour lui les calculs nécessaires. Aucune industrie ne peut vivre aujourd'-hui sans s'appuyer sur la Science.

Méthode Scientifique.

La méthode scientifique est tout autre chose que la simple documentation ; elle est plus utile encore. Sur ce point, malheureusement, il reste bien des progrès à faire. On est surpris de voir le mépris que professent pour la Science des ingénieurs ayant reçu la formation scientifique la plus complète. Aussitôt évadés des bancs de l'école, ils n'ont qu'une préoccupation : Faire de la pratique, comme ils disent, c'est-à-dire de l'empirisme, et ils se mettent à la remorque de leurs contremaîtres. La faute en est à la mauvaise orientation donnée à l'enseignement scientifique moderne, trop servilement dirigé vers la préparation aux examens, c'est-à-dire vers l'acquisition des faits particuliers qui constituent la Science acquise et fournissent d'excellentes questions d'examen.

Je voudrais rapidement passer en revue les principes essentiels de la méthode scientifique, c'est-à-dire l'ensemble des règles suivant lesquelles il faut conduire son esprit pour arriver le plus sûrement, le plus rapidement et le plus économiquement à la connaissance de la vérité.

Principe de Division de Descartes.

La première opération de la méthode est la division de chaque objet en parties plus simples. L'importance capitale de cette division tient à la faiblesse de notre esprit, incapable d'imaginer des objets trop complexes. Il voit d'autant mieux les faits et en raisonne d'autant plus facilement qu'ils sont plus simples. C'est là un des points sur lesquels Descartes insiste le plus longuement dans son Discours sur la Méthode.

Un second avantage de la division est que les parties les plus simples se retrouvent les mêmes dans beaucoup d'objets différents et leur étude une fois faite sert pour tous les cas semblables. Le sang est sensiblement le même dans tous les animaux et la chlorophylle dans toutes les parties vertes des plantes.

Enfin une division bien faite nous conduit à mettre en évidence des grandeurs mesurables. Quand nous avons déterminé les poids de phosphate de chaux, de carbonate de chaux et de gélatine renfermé dans les os des mammifères, nous acquérons une connaissance de ces os que ne nous aurait jamais donné le simple examen au moyen des seuls sens du toucher et de la vue.

On peut diviser un même objet de bien des façons différentes qui doivent varier suivant l'objet des études poursuivies. D'une façon générale, il faut tendre à séparer les parties les plus différentes, en laissant réunies les parties semblables. Par exemple, pour étudier un arbre, on ne le coupera pas en tranches horizontales par des plans équidistants, mais on séparera les racines, le tronc, les branches, les feuilles, les fleurs et les fruits.

On ne se contente pas enfin d'une seule division ; chaque partie d'un tout complexe est généralement elle-même composée d'éléments très différents : dans les feuilles, on distinguera les cellules, les canaux, la sève, le protoplasma. On pourra faire ensuite une troisième division et ainsi de suite jusqu'à ce que l'on arrive à des constituants élémentaires, c'est-à-dire à des parties que nous ne savons plus diviser. Les éléments constitutifs des feuilles sont formés de principes immédiats différents : cellulose, amidon, chlorophylle, etc. Ceux-ci à leur tour peuvent être divisés, par l'analyse chimique élémentaire, en carbone, hydrogène, oxygène et azote. Nous ne pouvons aller au-delà ; les corps simples de la chimie sont pour le moment la limite de la division réalisable.

Il n'est pas toujours nécessaire de pousser ainsi la division jusqu'aux grandeurs élémentaires indivisibles ; on peut souvent s'arrêter plus tôt, mais il faut toujours aller jusqu'à des grandeurs mesurables et qui de plus soient, autant que possible, des variables indépendantes, de façon à permettre dans les expériences de faire varier quelques-unes d'entre elles sans toucher aux autres. Nous reviendrons plus tard sur l'importance de cette dernière condition.

Définition de la Science.

Avant d'aller plus loin, il est nécessaire de bien définir ce que l'on doit entendre par le mot Science. Tous les phénomènes de la Nature sont liés les uns aux autres, sont engrenés de telle façon que tout changement dans certaines conditions entraîne nécessairement d'autres changements corrélatifs. On ne peut pas diminuer le

volume d'une masse gazeuse à température constante, sans augmenter sa pression ; les variations relatives du volume et de la pression sont égales et de signe contraire. Ces relations, ces lois s'expriment par des formules algébriques : la loi de Mariotte a pour formule

$$PV = \text{constante.}$$

L'objet exclusif de la Science est d'arriver à reconnaître ces lois et à les formuler.

Ces lois sont de complication très inégales. Celles de la Science pure, où l'on fait abstraction de tous les changements de la matière sauf un seul, celui que l'on étudie, sont les plus simples. Parfois, comme dans la loi de Mariotte, il n'y a que deux variables. Ces lois ont alors une généralité très grande : ce sont celles que les savants étudient de préférence dans leurs laboratoires.

Dans la Science industrielle, on envisage des lois d'une complexité beaucoup plus grande, par suite beaucoup plus difficiles à connaître et d'une moindre généralité. Dans les usines, on doit nécessairement tenir compte de toutes les propriétés de la matière, on n'a le droit de faire abstraction d'aucune d'entre elles. Il n'est pas rare d'avoir affaire à des fonctions d'une douzaine de variables et le nombre de ces relations est illimité ; la fin du monde viendra avant que nous ayons eu le temps de les étudier toutes. Chaque jour l'industriel doit s'attaquer à celles qu'il rencontre sur sa route. Un des exemples les plus célèbres de lois semblables étudiées dans l'industrie a été la loi formulée par Taylor pour la taille des métaux. Il a donné l'expression du prix de revient du poids de copeaux enlevés en fonction de douze variables différentes : Vitesse et profondeur de coupe, avance ; angles des faces, composition chimique, température de trempe et de revenu de l'outil ; dureté du métal travaillé ; robustesse de la machine, etc. L'établissement de cette loi a transformé toute la construction mécanique.

Division de la Méthode.

Comment s'y prendre pour résoudre au mieux et le plus économiquement possible les problèmes semblables que l'ingénieur rencontre journellement dans ses fabrications ? Telle est la question que nous allons aborder.

Pour étudier ce problème, nous commencerons par mettre en œuvre le principe de division. Nous diviserons la méthode en fonction du temps, envisageant séparément les opérations qu'elle doit exécuter successivement. Ce sont les suivantes.

1. Croyance au Déterminisme, c'est-à-dire à la nécessité des lois naturelles.

2. Fixation du but à atteindre.

3. Etude des moyens à employer pour atteindre le but désiré.

4. Réunion et mise-en-état des moyens de travail reconnus nécessaires.

5. Réalisation des expériences et études projetées.

6. Discussion des résultats, contrôle de leur exactitude, leur utilisation.

Déterminisme.

La croyance à la nécessité des lois est la base de toute Science. Il est inutile de parler de méthode scientifique, si l'on ne croit pas à la permanence et à l'inéluctabilité des relations qui engrènent les phénomènes entre eux. En théorie, tout le monde semble d'accord sur ce point, mais en pratique, on agit le plus souvent, surtout dans les usines, comme si l'on ne croyait pas aux lois; on admet l'intervention du hasard. La même fabrication répétée deux fois ne donne pas les mêmes résultats; personne ne s'en étonne. Ces irrégularités entraînent des déchets, on les accepte comme une plaie inévitable; c'est la négation même de l'esprit scientifique.

Il n'y a pas d'effet sans cause; si les résultats changent d'une opération à une autre, c'est que quelques-unes des conditions déterminantes ont été modifiées. Nous les avons laissées changer sans nous en apercevoir; c'est en cela seulement que consiste le hasard. Parfois des changements inappréciables à nos moyens d'observation peuvent avoir une influence considérable sur le résultat cherché, par exemple dans les métaux la présence d'oxygène dissous; le plus souvent, cependant, notre négligence seule est responsable de ces modifications passées inaperçues. La croyance active au déterminisme nous pousse à chercher la cause de toute anomalie et presque toujours elle nous la fait découvrir. Devant un acte de foi sincère, le hasard s'effondre rapidement. J'en ai vu souvent des exemples extraordinaires.

Un four à gaz ne voulait pas chauffer; en attendant le lendemain, me disait-on, il se remettrait sans doute de lui-même à marcher. Une simple analyse des fumées montra instantanément que le registre de la cheminée avait été mal reglé.

Un four Hoffmann présentait une allure irrégulière, cuisant un jour moitié moins de brique que l'autre. C'était la faute du hasard. En réalité, pendant le chargement des chambres, les ouvriers laissaient tomber des briques dans le carneau d'échappement des fumées, et le bouchaient plus ou moins complètement.

Que de fois voit-on sur les assiettes de faïence fine l'émail tressailler capricieusement. C'est un déchet normal que la plupart des usines acceptent philosophiquement. Si le consommateur était moins patient et se fâchait, les fabricants arriveraient bien vite à dépister le hasard. Le tressaillement est une simple question de

dilatation et celle-ci dépend de l'avancement des transformations de la silice contenue dans la pâte.

Fixation du But à Atteindre.

Il faut toujours donner à ses efforts un but *unique*, *précis* et *restreint*. C'est là une habitude très rare dans la vie courante et plus encore dans la vie industrielle.

Il faut viser un but *unique*. En poursuivant plusieurs lièvres à la fois on espère faire un travail plus profitable. Que de fois cherche-t-on du même coup à améliorer la qualité d'une produit et à diminuer son prix de revient. Trop souvent, même, on se propose de réaliser une amélioration sans savoir au juste laquelle on désire. Ce sont là des problèmes indéterminés, ne comportant aucune solution définie. En travaillant ainsi on est assuré de perdre son temps et son argent.

Voici au contraire un exemple de questions que l'on peut se poser utilement : Comment obtenir la qualité maxima pour un prix de revient donné ou le prix de revient minimum pour une qualité donnée. Une des raisons du succès de Taylor dans ses études sur la taille des métaux a été le choix judicieux de la question qu'il s'était posée : Prix de revient minimum du poids de copeaux enlevés sur un machine outil.

De plus le but doit être *précis* et pour cela il faut que le résultat cherché soit une grandeur mesurable. On ne doit jamais se placer dans l'obligation de se contenter d'appréciations de sentiments. Ce serait une erreur, par exemple, de se poser la question suivante : Quel traitement thermique appliquer à des outils pour leur donner la meilleure qualité possible ? La qualité est, en effet, une notion vague ne comportant pas de mesure, variable avec l'application envisagée et la mentalité des ouvriers. Mais on peut se demander : Comment traiter un outil donné pour lui faire enlever avant usure le poids maximum de copeaux sur une barre de dureté donnée ?

Il est nécessaire enfin de donner à chaque instant à ses efforts un but aussi *restreint* que possible. Autrement dit, il faut diviser chaque problème en ses différentes parties et n'en aborder qu'une seule à la fois. C'est ainsi qu'a procédé Taylor dans son étude sur la taille des métaux. Il a d'abord cherché l'influence de la vitesse de coupe, sans modifier en rien ses outils. Ensuite, il a étudié la meilleure forme à leur donner. Il a enfin abordé la question de leur composition chimique et celle de leur traitement thermique. Faute de ces précautions, les ingénieurs se découragent devant la longueur d'études qui n'aboutissent jamais et le patron recule devant des dépenses qui tardent trop à payer.

Etude des Procédés de Travail.

Une fois le but défini, il faut réfléchir aux moyens à mettre en œuvre pour l'atteindre. La première opération à faire dans ce but est la recherche des facteurs élémentaires dont dépend le problème étudié. Tantôt, on peut les prévoir à priori, en s'aidant de connaissances antérieurement acquises, d'autres fois il faut entreprendre une étude spéciale pour les découvrir. Nous laisserons de côté le second cas, dont l'étude nous entraînerait trop loin. Il suffira de rappeler ici que les méthodes à suivre pour cette découverte ont été exposées d'une façon magistrale par Claude Bernard dans son " Introduction à l'étude de la médecine expérimentale."

Dans le premier cas, qui est le plus simple et le plus fréquent, le problème consiste à diviser et à subdiviser les facteurs connus de façon à mettre en évidence des grandeurs mesurables qui soient en même temps des variables indépendantes. Prenons comme exemple la fabrication des briques de silice. Notre but est d'obtenir la plus grande résistance à l'écrasement à une température donnée, à 1600°, par exemple. Cette résistance dépend évidemment de la porosité de la brique ; de la proportion et de la fusibilité du magma qui réunit les grains de silice ; de l'état chimique de cette silice (quartz ou tridymite). Ces diverses grandeurs sont plus ou moins facilement mesurables, mais ce ne sont pas des variables indépendantes ; la porosité est fonction de la proportion du magma fusible et de l'état de la silice. Voici au contraire pour le même problème des facteurs qui réunissent les trois conditions d'être mesurables, indépendantes et même élémentaires : Composition chimique élémentaire, composition granulométrique ; proportion d'eau de gâchage ; compression de moulage ; température et durée de cuisson.

Une seconde considération très importante à faire intervenir dans cette étude préalable est celle du prix de revient. Les recherches industrielles doivent payer, c'est-à-dire rapporter plus qu'elles n'ont coûté. Il ne faut donc pas, comme les savants de laboratoire sont trop habitués à le faire, prendre toujours les appareils les plus précis, partant les plus coûteux, et moins encore faire construire un nouvel appareil pour chaque nouvelle recherche. Ce serait du gaspillage. Les dépenses, tant en appareils qu'en personnel, croissent suivant une fonction très rapide de la précision, tandis que l'utilité ne croît que suivant une fonction décroissante de la même précision. Remplacer le pouce et l'œil par des appareils de mesure donnant seulement la précision du dixième est extrêmement utile et peu coûteux. Pour passer de la précision du dixième à celle du centième, la dépense devient considérable tandis que le bénéfice

croît très peu.   Enfin la précision du millième est généralement sans aucune utilité pratique et entraîne des dépenses sans limites.

Cette préoccupation du prix de revient conduit encore à classer les divers facteurs par ordre d'importance et à commencer leur étude par celle des plus importants, en sacrifiant au besoin les derniers.   La qualité des briques de silice dépend certainement de la nature et de la proportion de chacun des oxydes basiques contenus : les alcalis donnent plus de fusibilité que la chaux et la chaux plus que l'alumine, mais ce sont là des nuances que l'on peut négliger dans un premier examen.   La somme totale de ces oxydes basiques est, au contraire, un facteur dominateur auquel on peut limiter son attention.   Il en résulte une très grande simplification et une très grande économie dans les analyses chimiques.

On réduit encore les frais d'études, en limitant celles-ci à la zone réellement utile pour le but pratique poursuivi.   Il est cependant nécessaire de dépasser un peu les limites intéressantes pour mieux préciser la forme des fonctions algébriques représentant les lois cherchées.   Si l'on voulait déterminer la direction de la tangente à une courbe en utilisant seulement deux points voisins de la courbe, on trouverait, en raison des erreurs expérimentales inévitables, une direction quelconque.   Dans la fabrication des briques de silice, il est inutile de faire varier la proportion des fondants de 0 à 100%, puisque la zone utile est comprise entre 3 et 6%.   Il est indispensable cependant de pousser les études de fusibilité en dehors de ces limites, depuis 2 jusqu'à 8% au moins et mieux de 0 à 10%.   On s'exposerait sans cela à formuler des conclusions entièrement faussées par les erreurs expérimentales ; on trouverait peut-être que la fusibilité décroît quand on augmente la proportion des fondants.

Un point très important à examiner dans cette préparation des recherches est celui de l'échelle de grandeur à adopter pour les opérations projetées.   Les essais doivent-ils porter sur des quantités de matières comparables à celles que l'on met en œuvre dans les opérations industrielles, c'est-à-dire sur des tonnes de matières, ou bien peut-on se contenter d'opérer que quelques grammes, comme cela se fait dans les laboratoires scientifiques ?   C'est une question d'espèce.   Si on a le moyen de définir et de mesurer toutes les grandeurs entrant en jeu dans l'opération projetée, il faut sans hésiter se contenter d'opérer sur des grammes ; c'est beaucoup plus rapide et plus économique ; les résultats obtenus ainsi valent encore pour des tonnes et des milliers de tonnes.   Souvent cependant il est difficile de mesurer certains facteurs dépendant des dimensions des appareils ou des matières, comme la perte de chaleur par les parois des fours ou la diffusion des gaz à l'intérieur de gros morceaux de minerais de fer.   Dans les usines où l'on dispose de moyens d'action

puissants, il peut être avantageux cependant de faire les expériences à l'échelle d'exécution. On se dispense ainsi de mesurer certains facteurs difficiles à atteindre.

Une dernière condition essentielle dans la préparation des expériences est de les combiner de façon à ne faire jamais varier à la fois qu'un seul facteur du phénomène étudié et de procéder toujours par comparaison entre deux expériences ne différant que par la grandeur d'une seul variable. Dans ses mémoires, F. Taylor insiste vivement sur la nécessité de cette règle. Quand on a réussi, dit-il, à maintenir toutes les conditions, sauf une invariable, on a aux trois quarts réalisé les expériences. Il a d'ailleurs joint l'exemple au précepte. Dans ses recherches sur la culture du gazon de golf, il planta un millier de petits carrés de gazon de 1 m.² chaque, groupés deux par deux, de telle sorte que deux carrés conjugués ne diffèrent jamais que par une seule condition.

Préparation des Moyens de Travail.

Il y a grand intérêt à réunir à l'avance les moyens de travail dont on aura besoin : Matières, premières, outils, personnel. On gagne beaucoup de temps et l'on fait de meilleure besogne. Si l'on se met au travail, avant d'avoir tout préparé, on est bien vite arrêté; pendant que l'on attend les objets manquants, on perd le souvenir du travail déjà fait et on doit le recommencer. On voit ainsi dans les usines des études durer des années; elles coûtent dix fois plus cher que si elles avaient été conduites d'affilée. On finit par perdre de vue le but du travail en cours et finalement les résultats trop tardifs ont perdu tout intérêt quand on les obtient ou même l'on n'aboutit pas du tout.

La préparation des matières à étudier comprend la vérification de leur pureté, ou plus généralement de leur composition, de leur état de conservation. Pour étudier les propriétés d'un ciment, il ne faut pas partir d'un produit éventé; pour mesurer la ténacité d'un fil métallique, il ne faut pas l'avoir laissé rouiller avant les expériences. On ne peut pas étudier utilement la fabrication de briques de silice avec un quartz trop impur.

Les appareils mis en œuvre doivent non seulement être amenés à pied d'œuvre à l'avance, mais leur bon fonctionnement doit être vérifié. Si l'on opère sur des fluides, gaz ou liquides, l'étanchéité est une condition de première importance. L'uniformité de température dans les fours, l'exactitude des dimensions des formes de moulage, le graissage des surfaces frottantes, etc., demandent un examen minutieux.

Enfin, et par dessus tout, les appareils de mesure doivent être

bien réglés, étalonnés et toujours vérifiés dans des expériences à blanc, faites dans des conditions de fonctionnement aussi voisines que possible de celles où l'on opérera ensuite. Pour l'analyse chimique, on vérifie les poids de sa balance, on contrôle ses liqueurs titrées en les employant au dosage d'un corps pur. De même pour les mesures de températures élevées, on refait la graduation des couples thermoélectriques. Ce sont là des sujétions longues et ennuyeuses, mais cela est peu de chose auprès du désagrément auquel on s'expose en faisant une longue série de mesures au moyen d'un appareil dont on ne reconnaît l'inexactitude qu'après l'achèvement du travail.

Réalisation des Expériences.

Une fois le programme de recherche bien arrêté et tout le matériel nécessaire préparé, la réalisation des expériences est relativement simple. Le plus souvent, on peut confier le travail à de simples manœuvres ; cela est plus économique. C'est cependant là un point souvent discuté : peut-on avoir la même confiance dans une main-d'œuvre ignorante que dans celle de chimistes, de physiciens, d'ingénieurs connaissant en plus de la pratique la théorie de leur métier ? Au point de vue de la seule précision des mesures, les manœuvres valent autant et souvent mieux que les diplômés des écoles scientifiques ou techniques. A un autre point de vue, cependant, ces derniers ont une grande supériorité ; ils seront capables de saisir au vol tout fait nouveau qui viendrait accidentellement se présenter au cours de recherches ayant un but précis, mais différent. Si Auer avait fait faire ses analyses de terres rares par des manœuvres, il n'aurait pas eu l'occasion d'observer l'incandescence exceptionelle de la thorine. C'est là une question d'espèce ; certaines études ne comportent guère de chance de découvertes nouvelles, par exemple l'analyse journalière des mêmes minerais de fer ; elles doivent alors être confiées sans hésitation à des manœuvres. Par contre l'étude de minerais inconnus, de provenance lointaine, sera plus utilement faite par un véritable chimiste.

Dans la réalisation des expériences deux règles essentielles doivent être suivies. Il faut noter avec grand soin toutes les conditions des expériences. Certaines d'entre elles semblent sur le moment être dépourvues d'intérêt et plus tard on se rendra compte que faute de certains renseignements négligés, on ne peut pas tirer tout le parti que comportaient les études faites. C'est encore un point sur lequel F. Taylor insiste tout particulièrement et qu'il recommande avec insistance à l'attention des jeunes ingénieurs. Vous avez mesuré par exemple la résistance à chaud d'une brique de silice, en la rapprochant de sa composition chimique et de sa température

de cuisson, mais vous n'avez noté ni la densité absolue de la brique, ni sa porosité, qui ne vous intéressaient pas au moment des expériences.   Plus tard, vous vous apercevrez que le gonflement dû à la transformation finale de la silice amène une chute considérable de résistance.   Ignorant l'état du quartz, que vous aurait donné une mesure rapide de densité, vous ne pouvez tirer aucun parti de vos anciennes expériences.

Une seconde règle non moins essentielle est de s'astreindre à suivre rigoureusement le programme arrêté tout d'abord.   On croit pouvoir l'améliorer en cours de route et sans y réfléchir d'avantage, on abandonne la direction première ; bientôt on se met à travailler au hasard sans aucune méthode.   Il n'est plus possible ainsi de faire de travail fructueux.   Ce changement est particulièrement grave, si les expériences sont faites par un opérateur distinct du chef des études, de celui qui a arrêté le programme.   Ignorant les conditions des expériences, il ne peut tirer aucune conclusion des résultats obtenus ; c'est du travail entièrement perdu.   C'est là un cas très fréquent ; un sousordre chargé d'un essai croit bien faire, en s'inspirant de son expérience personnelle, pour modifier le programme qui lui a été indiqué, pensant obtenir ainsi un résultat plus avantageux, mais en se gardant bien de dire comment il l'a obtenu. C'est du désordre et le désordre est toujours improductif.

Conclusion : Contrôle et Applications.

Une fois les expériences faites, il faut en tirer la conclusion. Celle-ci est presque toujours une relation entre un résultat cherché et les facteurs dont il dépend.   Ce résultat sera parfois énoncé verbalement et d'une façon purement qualitative.   Pour avoir plus de précision, on pourra traduire ce résultat par une courbe géométrique.   On aura souvent dans ce cas intérêt à faire des changements de variables.   Au lieu de porter abcisses les grandeurs directement mesurées, on pourra prendre leur inverse, leur logarithme ou toute autre fonction simple de ces grandeurs.   Toutes les fois que l'on peut par des transformations appropriés arriver à une courbe voisine d'une droite, il y a avantage à le faire.   Cela augmente beaucoup la précision des interpolations et plus encore des extrapolations.   Enfin, il faut choisir l'échelle des abcisses de telle sorte que la courbe présente une inclinaison moyenne se rapprochant de 45°.

L'emploi des formules algébriques pour réunir un certain nombre de résultats facilite les calculs ultérieurs auxquels on peut avoir à soumettre les données de l'expérience.   En raison de l'imprécision inévitable des mesures, il y a un grand nombre de formules algébriques qui peuvent représenter également bien les résultats des mesures.

Dans le choix arbitraire de ces fonctions, il est utile de se préoccuper de la considération des limites, c'est-à-dire prendre une forme de fonction qui ne conduise à aucun résultat absurde pour les valeurs nulles ou infinies de la variable. Par exemple, il ne faut jamais, pour représenter une grandeur qui peut croître sans limite, comme le rayonnement, par exemple, prendre une fonction parabolique qui conduit souvent à un maximum ou un minimum incompatible avec la nature même du phénomène à représenter.

Le second point à examiner est la discussion du degré de précision que comporte le résultat obtenu. On cherche d'abord la relation qui existe entre la précision de ce résultat et celle de la mesure de ses différents facteurs. Très souvent cette relation peut s'exprimer simplement au moyen d'une différentielle logarithmique, donnant l'erreur relative sur le résultat sous forme d'une somme d'erreurs relatives concernant chaque mesure individuelle des facteurs.

On distingue les erreurs accidentelles des erreurs systématiques, en se rappelant bien que ces dernières sont en général de beaucoup les plus importantes. Aussi le mal que l'on se donne souvent pour corriger les erreurs accidentelles est tout à fait illusoire. Appliquer à des problèmes industriels, comme on le fait parfois, la méthode des moindres carrés, est une folie. Pour tirer de plusieurs mesures divergentes une valeur qui présente le maximum de garanties d'exactitude, on fait généralement la moyenne arithmétique des résultats, après avoir supprimé quelques-uns d'entre eux que l'on juge moins bons, soit à cause des conditions même de l'expérience, soit simplement par ce qu'ils s'écartent plus des autres. C'est là une habitude fâcheuse. On devrait toujours prendre le nombre probable, que l'on obtient en rangeant les résultats dans l'ordre de leur grandeur décroissante et retenant seulement celui du milieu de cette liste. Les résultats anormaux placés aux extrémités de la liste s'éliminent d'eux-mêmes, sans aucun choix arbitraire.

Les erreurs systématiques sont bien plus importantes et les plus difficiles à éviter car le plus souvent on ne les connaît pas. On les laisse subsister seulement par ce que l'on en ignore l'existence. Une des causes les plus fréquentes d'erreurs systématiques dépend de l'échelle réduite de grandeur à laquelle on fait la plupart des expériences. Certains facteurs dépendant des dimensions ou de la durée des opérations sont intervenus, sans qu'on s'en aperçoive. On se prémunit contre cette cause d'erreur, en faisant, avant les applications pratiques, des essais semi-industriels, c'est-à-dire à une échelle intermédiaire entre celle du laboratoire et celle de l'usine. Cela permet de reconnaître l'intervention de certains facteurs qui ne s'étaient pas manifestés dans les expériences faites en petit. C'est là une précaution toujours très utile ; on n'est jamais infaillible.

La troisième phase de la conclusion finale est de passer de l'expérience de laboratoire à l'application industrielle. La difficulté provient de ce que dans l'expérience de laboratoire on se préoccupe peu ou pas du prix de revient. Les expériences faites à petite échelle sont relativement peu coûteuses; on y dépense peu de combustible, peu de matière première, pas du tout de force motrice. Pour passer du laboratoire à l'usine, il faut combiner des procédés qui permettent de réaliser économiquement, mais par des procédés tout à fait différents, les conditions de température, de composition, de vitesse, etc., reconnues les plus avantageuses au laboratoire. Il faut mettre en jeu toutes les ressources de son expérience industrielle. C'est ici l'ingénieur et non plus l'expérimentateur qui doit intervenir.

Champ d'Application.

Arrivé au terme de cette étude des voies et moyens de la méthode scientifique, on va se demander : Quand faut-il donc employer la méthode scientifique ? Une usine est un instrument de production et non un laboratoire de recherche scientifique. Faire de la recherche est un luxe que peuvent se payer les affaires très riches, mais qui n'est pas à la portée des petites entreprises.

C'est une erreur; dans toute usine si petite soit-elle, on fait toute la journée de la recherche, qu'on le veuille ou non. A chaque instant il se présente de nouveaux problèmes à résoudre. La seule question à se poser n'est pas s'il faut ou non faire de la recherche, mais seulement comment on doit faire la recherche. Faut-il se contenter de recherches empiriques ou essayer d'y appliquer la méthode scientifique ? Le rendement, la qualité, le prix de revient varient d'un jour à l'autre; pourquoi ? Quel jour ne se pose-t-on pas cette question ? Un client se plaint de la qualité d'une livraison; le défaut est-il réel, peut-on l'éviter ? Un concurrent vous enlève votre clientèle par la qualité supérieure de sa marchandise; comment l'égaler ? On répond généralement à toutes ces questions en s'appuyant seulement sur ses connaissances acquises et sur des raisonnements. Ne vaudrait-il pas mieux faire une étude méthodique; ne serait-ce pas plus économique ? C'est là toute la question que je soumets à vos méditations.

SORBONNE UNIVERSITY,
    PARIS.

XXIVa.—*The Scientific Method in Industry.*

By PROFESSOR HENRY LE CHATELIER.

IT is with the greatest interest that I have studied the Journal of your Society since its inauguration. I appreciated the importance that you attached to scientific research and the confidence that you placed in it for the furtherance of your industry. You will therefore not be surprised that I have chosen as a subject for this conference a study of one of the points of contact between science and industry.

The Relationship of Science to Industry.

That the wonderful developments of modern industry have been the direct consequence of scientific progress the world to-day readily admits, often indeed without consideration of the spheres in which its applications have been most exerted. We live to-day so much amidst these applications that, like the Parisian who, on account of his continual proximity to the Seine, does not perceive those magnificent perspectives which hold the stranger entranced ; so we do not perceive their presence. To understand readily the industrial importance of science it is only necessary to wipe out in thought those industries particularly dependent on it, and, this operation done, one finds that nothing remains. Take from metallurgy chemical analysis, the measurement of high temperatures, the laws of elasticity, etc., and you are left with the metallurgy of Central African negroes. Deprived of the laws of Ohm, Faraday, and Ampère, electrical engineering or anything of that nature would be impossible, and further, there is every reason to believe that any new developments in industry will be due primarily to science. This question of the influence of science on the progress of industry should grip the attention of those who, like yourselves, have the responsibilities of important industrial concerns.

In the first place, how does Science operate in the development of an industry ? Its influence is twofold. The scientific worker may in the first place utilise scientific knowledge, or in the second place apply, to the problems which beset him, the scientific method.

The Gifts of Science.

The gifts of science are first of all the general laws. The laws of Ohm and Ampère form the basis of all the necessary calculations in the construction of a dynamo; the laws of Mariotte (Boyle's Law) and of Gay-Lussac interpose themselves in the study of all classes of steam and motor engines and of freezing machines, etc.; whilst the laws of Lavoisier form the basis on which analytical chemistry has been built up.

The knowledge of these laws enables us to utilise the material things of this world; it permits us to direct its natural forces to our interests, and after all that is the primary object of industry.

In the second place, scientific measurements afford us invaluable means for regulating the work of our factories and for preventing losses. For instance, no one would think nowadays of putting iron-ores into a blast furnace without knowing from analysis their constitution, nor of tempering the main shaft of a motor without having taken the temperature, nor even of putting an electric furnace into operation without having an ammeter in circuit. Indeed, the replacement of rule of thumb observations by scientific methods has been sufficient in itself to revolutionise many industries.

Finally, the laboratory worker may stumble on facts which may prove of enormous value to the arts and crafts. It was the observation made by Auer of the extraordinary light produced by thoria when heated in a Bunsen flame that led to the formation of an industry in incandescent gas lighting. The discovery in scientific laboratories of the aniline colours gave a tremendous impetus to the great dyeing industry. Neon, helium, and argon, found in air by Ramsay, have been used, the first for luminescent illumination, the second for filling balloons, and the third for filling tungsten lamps.

In regard to the utilisation of scientific principles we stand to-day on a fairly sound footing; the large Technical Colleges and Universities of every country are producing industrialists, engineers and chemists well grounded in scientific matters.

One may say, however, that there are many small manufacturers and employers of labour who produce articles of commerce without the faintest notion of science. They follow in the footsteps of Monsieur Jourdain, utilising science without being aware of the fact. The small bicycle manufacturer who fits in ball bearings, the result of years of study on the properties of chrome steels and their tempering conditions, unknowingly profits by these scientific researches; and in the same way the small contractor who employs I-bars in his constructions may be unaware of the reason for their

curious form. He may know nothing about moments of inertia and when coming to decisions on his dimensions he may refer to his pocket-book wherein men of science have made for him every necessary calculation. There is not one industry which can exist nowadays without leaning in some way or other on science.

The Method of Science.

Scientific method means more than simply to be well informed on scientific subjects; it is infinitely more useful; yet on this point, unfortunately, much progress remains to be made. One is sometimes surprised to note the scorn affected for science by some of those who have received the most complete scientific education. The school bench has no sooner been left behind than they are obsessed with one idea—to engage in " practical work." They may say this as a sop to Cerberus in the shape of their employers or foremen, but the fault lies largely with the modern tendencies in scientific teaching where the student is too carefully guided along paths indicated by preparatory work for examinations, that is to say, towards the acquisition of certain fundamental facts which, however, furnish excellent opportunities for examination questions.

I shall now briefly pass under review the essential principles. which form the basis of scientific method, that is to say, those rules which must be followed in order to ascertain facts in the most certain, rapid and economical way.

Descartes's Principle of Division.

The first operation of the method consists in the sub-division of each object into its most simple constituents. The supreme importance of this division is accounted for in the weakness of our brains, incapable of conceiving anything of a complex nature. This operation carried out, we are enabled to appreciate with greater ease facts which are the more readily perceived as the object becomes simplified. This was one of the points on which Descartes laid so much stress in his Treatise on Method.

There is a second advantage in this division, and that is that many of the more simple bodies are found elsewhere; and once their study has been accomplished it serves in every similar case. Blood, for instance, is nearly the same in all animals, and the properties of chlorophyll, where it occurs in green plant-life, are almost identical in every case.

When this sub-division has been successfully accomplished, we are left with certain measurable quantities. When we have determined the respective weights of calcium phosphate, of calcium carbonate, and of gelatin to be found in the bones of mammals, we

have acquired information about these bones which we should not
have obtained by a simple hand-and-eye observation.

There are many different ways of sub-dividing an object, which
may be varied according to its nature. In a general way, the
tendency must be to separate those parts least resembling one
another, and to allow the more closely allied quantities to remain
together. For instance, in order to study a tree, one would not cut
it into horizontal sections of equal thickness, but would separate
one from another, the roots, the trunk, the branches, the leaves, the
flowers, and the fruit.

Nor would one remain content with only one sub-division, for
each part of the complex whole is generally in itself composed of
widely different substances; in the case of the leaves, it is possible
to differentiate between the cells, the veins, the sap, and the proto-
plasm; and one might go further until one had arrived at the ele-
mental constituents, that is to say, to those parts that we cannot
further sub-divide. The substances of which a leaf is constituted
are immediately different : cellulose, starch, chlorophyll, etc.; and
these in turn may be further sub-divided by chemical analyses
into the elements, carbon, hydrogen, oxygen, and nitrogen. We
cannot go beyond that. For the moment, the chemical elements
are the limit of our sub-division.

It is not always necessary to go so far in our sub-division as the
chemical elements; one can generally stop before that; but,
nevertheless, one should get down to measurable quantities of what
are, as far as possible, independent variables; so that one may be
able to vary at will any one or two of these without in any way
altering the others.

Later we shall have an opportunity to observe the importance of
this last condition.

Definition of Science.

Before going further, it becomes necessary to define that which
should be understood by the word " science." All the phenomena
of nature are so related the one to the other that when any change
occurs in any one phenomenon it brings with it changes in one or
other of its correlated conditions. One cannot diminish the volume
of a gaseous mass at constant temperature without increasing its
pressure; the relative variations of pressure and volume are equal
and of opposite sign. These relationships, or rather laws, may be
reduced to an algebraic formula. Mariotte's Law (Boyle's Law),
for instance, has the formula

$$PV = \text{constant},$$

and the exclusive object of science is to find and become acquainted with these laws and to find formulæ to serve them.

These laws, however, are unequally complicated. Those of pure science, where every change in a material is ignored save one (that which, at the time, is being studied), are the most simple. Occasionally, as in Mariotte's Law (Boyle's Law), there are only two variables. These laws have therefore an enormously wide application, and they are those which men of science like best to study in their laboratories.

In industrial science, however, one finds laws of a much greater complexity, and these are more difficult as they are less wide in their application. In factories, one must necessarily take into account every variable in the properties of a material. None of these may be neglected, even in dealing with a function having as many as a dozen variables, in which the number of combinations is almost limitless. We might reach the end of the world without having had time to study them all individually. Each day the manufacturer is brought face to face with problems which must be attacked.

One of the most celebrated of these problems resulted in the formulation of a law by F. W. Taylor on the cutting of metals. He gave a factor for the selling cost by weight of the filings or turnings removed in a function of twelve variables—the speed and depth of cut, the extent or area of cut, the angles of the cutting faces, the chemical composition, the annealing temperature, and the back-thrust of the tool, the price or cost of the metal worked, the robustness of the machine, etc. It was the establishment of this law that assisted in the revolution of mechanical construction.

The Division of Method.

We shall now endeavour to deal with that method whereby the scientific worker in the factory may gather together and deal most economically with those problems which confront him daily.

In order to study this problem, let us put into operation the principle of division which we have just outlined. We shall divide method into functions of time, visualising the operations which must be followed successively.

They are as follows :

1. Belief in determinism, that is to say, in the necessity for natural laws.

2. Fixing the end to be obtained.

3. The study of the means to be employed for the attainment of that end.

4. Getting together and preparing the means found to be necessary.

5. Carrying out the experiments and studies projected.

6. Discussion of the results ; control of their accuracy—utilisation of the facts obtained.

(1) *Determinism.*

The belief in the necessity of laws is the foundation of all science. It is useless to talk of scientific method if one does not believe in the permanence and applicability of the relationships on which natural phenomena are mutually hinged. Theoretically, everyone will admit this point, but in factories it is not an uncommon thing to find people whose attitude to their problems might lead one to think that they did not believe in these laws, for they admit the intervention of chance. A process of manufacture is repeated a second time, but does not give the same results ; no one is astonished. These irregularities bring with them losses which are accepted as inevitable—that is the very opposite of the scientific spirit. There is no effect without a cause ; if results change from one operation to another, then one of the determining conditions must have been modified. We have allowed them to change without noticing the fact. Thus only can chance occur.

Occasionally changes, inappreciable to our limited means of observation, may have a considerable influence on the desired results, as, for instance, the presence of dissolved oxygen in metals ; but much more often it is only our negligence that is responsible for those modifications, which have crept in unperceived. It is the active belief in determinism that urges us to look for the cause of all anomalies, and nearly always it enables us to discover the unknown variable.

Faced with an act of sincere belief in determinism, chance vanishes rapidly. I have seen some extraordinary examples of this.

For instance, I was told that a gas-fired furnace would not get hot, but if we waited till the morrow it would probably run well. A simple analysis of the flue gases instantly showed that the chimney damper had been badly regulated.

A Hoffman kiln exhibited most irregular behaviour on one day, firing only half as many bricks as on another. It was due to chance !

Actually, in charging the kiln chambers, workmen had allowed bricks to fall into the exit flues and had almost completely blocked them.

Often one may find that the enamel on earthenware is most

capriciously crazed. It is a normal loss that the greater number of factories philosophically accept.

If the purchaser were less patient and became annoyed, the manufacturer would speedily seek some method of dissipating " chance." The crazing is simply a question of expansion, and this will depend on the exact state of the silica in the body.

(2) *Fixing the End to be Attained.*

It is always necessary to have an objective, single, precise, and of small magnitude ; yet it is a habit rarely found in the general life of to-day, and perhaps even still less in industrial life.

There must be only one single object. One may seek to work more profitably in studying more than one problem at a time, to better a product whilst reducing its selling price. Too often, again, it is proposed to improve a product without exactly knowing what one wants. These are not determined problems presenting a definite solution, and in tackling them, one stands to lose, not only one's time, but also one's money.

On the other hand, a question which might be solved with advantage would be " How to obtain the best quality at a given selling price," or again " What would be the lowest selling price for a given quality ? " One of the reasons for Taylor's success in dealing with industrial problems was his judicious choice of the questions he put to himself. " The minimum selling cost by weight of the turnings removed from an engineer's tool."

Further, the end must be precise, and for this it is essential that the end sought for should be a measurable quantity. One should never be placed in the position of having to be content with approximations dependent on sentiment. It would be a mistake, for instance, to ask the question, " What thermal treatment should be applied to tools in order to give them the best possible quality ? " Quality, after all, is only a vague notion which has no measurable dimensions. It is variable according to the standards and mentality of the individual workman. On the other hand, the question might be stated in this way : " How must a given tool be treated in order that before wearing out it may remove the largest weight of turnings from a bar of given hardness ? "

Finally, the end should be as restricted as possible. In other words, any subject tackled must be divided into its constituent parts and a second part not tackled until the first has been thoroughly completed. It was in this way that Taylor worked in his experiments on the cutting of metals. First he studied the influence of speed on the nature of the cut without in any way modifying his tools, then he

studied their shape; finally, he tackled the problems of chemical composition and of thermal treatment.

Faced with these precautions, the scientific worker is apt to be discouraged with the extent of the studies involved, whilst the employer hesitates before expenditure which will be so long in bringing results.

(3) *The Study of the Processes to be Employed.*

The end once defined, it is necessary to consider the means whereby it is to be brought about. The first operation consists in looking for those elementary factors on which the problem to be studied depends. It may be that in following the foregoing process they have already been determined, but, if not, it may necessitate a special study to discover them. We shall not deal with this second case, for it presents so many aspects that to study them would not only take up too much of our time, but would also take us too far from our objective. It is sufficient to recall the fact that a very full description of the methods to be followed has been given by Claude Bernard in his " Introduction to Elementary Medicine."

In the first, most simple and most frequent case, the problem consists in dividing and sub-dividing the known factors in such a way as to keep in evidence measurable quantities of what are at the same time independent variables. Take, for example, the manu-facture of silica bricks; if our end is to obtain the greatest resistance to squatting under load at given temperatures up to, say, 1,600°, then we may study the porosity, the proportion and fusibility of the bond which unites the grains of silica, and the chemical state of the silica (quartz or tridymite).

These different quantities are all more or less easily measured, but they are not independent variables. The porosity is a function of the proportion of fusible bond and of the state in which the silica exists. On the other hand, we have the following factors which bear on the problem and satisfy the three requisite conditions, namely, measurability, independence, and even simplicity. (1) Elementary chemical composition; (2) grain sizes; (3) the proportion of water required to produce plasticity; (4) the pressure on the mould, and (5) the time and temperature of firing.

A further consideration at this stage is the question of the ultimate financial return. Industrial research must pay for itself; that is to say, the revenue resulting from it must be more than the expenditure involved. For that reason, one must avoid the use of apparatus of too great precision, however much it may be favoured by the laboratory scientists. These pieces of apparatus are expensive, and it is scarcely necessary to add that a new apparatus should not

require to be constructed for each investigation. That would be sheer waste. The cost of an investigation which needs as much in apparatus as in staff increases with the precision desired, whereas the utility of the result is only slightly increased.

To replace, however, rule of thumb methods by apparatus giving a precision of only one-tenth is extremely useful, but it is also inexpensive. To increase the precision of the result from one-tenth to one-hundredth, a very considerable increase in expenditure is required, whereas the utility is only slightly increased, whilst the precision of one-thousandth is generally without practical utility and entails almost limitless expense.

This consideration of the financial return obliges us to classify the different factors in the order of their importance and to commence their study by a consideration of the more important ones, sacrificing of necessity the remainder. The quality of a silica brick depends on the nature and proportion of each of the basic oxides present. The alkalies give greater fusibility than lime, and lime than alumina, but these are differences that one may neglect in a first examination. On the other hand, the sum total of the basic oxides present is a dominating factor to which primarily one may limit one's attention. The result is a great simplification and economy in the chemical analysis.

One can further reduce the cost of these examinations in limiting them to the really useful zone, covering that end which is being sought for in practice. At the same time, it is necessary to exceed by a small amount the limits of greatest interest in order to be more certain of the form of the algebraic functions which are to be used to represent the laws in question. If one desired to obtain the tangential direction at any point of a curve, using only two neighbouring points, one might find that, on account of inevitable experimental errors, almost any direction could be obtained. In the case of the manufacture of silica bricks, it would be useless to vary the proportion of fluxes from 0 to 100 per cent. when the useful zone only lies between 3 and 6 per cent., but necessary, on the other hand, to examine the fusibilities of bricks containing from 2 to 8 per cent. or better still from 0 to 10 per cent. Without doing this it might be possible to formulate entirely erroneous conclusions on account of experimental errors. One might find, for instance, that the fusibility decreased as the proportion of fluxes increased.

A further important consideration in the preparation of the mediums of research is the scale on which such research is to be carried out. The tests made must of necessity bear a definite relationship to the quantities of material used in practice, but one may operate either in tons or grams, as is done in scientific labora-

tories. It is simply a question of species. If one has the means of defining and measuring all the quantities which come into operation during the projected study, one must not hesitate to be content with studies in gram magnitudes. Not only is this more rapid, but it is more economical, and at the same time the values obtained are equally applicable to tons or to thousands of tons. At the same time, it is often difficult to measure certain factors dependent entirely on the dimensions of the apparatus to be used or of the materials, as, for instance, the loss of heat by conduction and radiation from furnace walls or the diffusion of gases into the interior of iron-ores. In factories where there is the opportunity of doing so, it may be advantageous to experiment on the scale of normal working practice.

A final condition which is most essential in the preparation of the mediums of research and of experiments is that the latter should be so combined as to permit of the variation of only one factor at any one time. Thus, it should be possible to compare the results of two experiments differing from one another by the magnitude of a single factor. In his monograph on the subject, F. Taylor laid particular · emphasis on the necessity for this rule. When one has succeeded, he states, in maintaining the invariability of all conditions save one, three-quarters of the investigation has been accomplished; and, further, he put his precepts into practice. In his researches on the condition of golf greens, he planted a thousand small squares of sward each about a yard square, grouped in such a way that two conjugate squares differed from one another by only one single condition.

(4) *Preparation of the Apparatus.*

It is a matter of primary importance that all the apparatus which will be required for a research should be gathered together beforehand : materials, tools, staff, etc. Not only is time saved, but better work is accomplished. To start any operation without having every requirement at hand is useless, for one is speedily stopped by the lack of an essential material, and whilst it is being procured the memory of that which has gone before is dissipated and it becomes necessary to recommence operations. On this account, one may find researches proceeding in factories which have lasted for years, and have cost ten times as much as if they had been done systematically. Too often the end becomes obscured and the results obtained have lost interest because they have been reached when no longer required, perhaps even they may have entirely missed the point.

The preparation of those materials required includes, further, the

investigations relative to their purity, accuracy, and state of preservation. In studying the properties of cements, one must not neglect to sample an initially dried product. For the measurement of the tenacity of metallic wires it is essential that they should not be rusted prior to the experiment, or again it would be useless to study the properties of silica bricks if the quartz itself had too high a content of impurities.

Not only must the apparatus required be brought on to the scene of operations well in advance, but its accuracy must be tested and it must be functioning properly. When fluids, whether liquid or gaseous, are being operated with or on it is necessary that there should be no leakage. The uniformity of temperature in the furnace, the dimensions of the articles employed, the friction on rubbing surfaces, all these demand the most careful attention beforehand.

And finally, perhaps most important of all, there is the standardisation, regulation and verification of the apparatus to be employed. This is done by blank measurement, as nearly as possible under those conditions which will exist during the course of the investigation. In a chemical analysis, the weights of the balance must first be verified, then the solutions used for titration are verified by standardisation against fixed quantities of bodies known to be pure, and in the same way the graduations on an electric thermo-couple should be carefully standardised prior to the measurement of high temperatures. These operations are not merely lengthy, but are tedious and annoying, yet they are of little account when compared with the annoyance of a disagreement in results to which one may be exposed by means of an apparatus the inaccuracy of which one only recognises after the results have been obtained.

(5) *The Carrying out of the Experiment.*

When the programme of research has been thoroughly well arranged and all the necessary material prepared, the carrying out of the experiment is relatively simple. In many cases this may be left to ordinary mechanics; which, although a much-disputed point, is by far the more economical. Can one have, however, the same confidence in a result obtained by the hand of an unskilled help as in that obtained by a skilled chemist or physicist who has all the theory of his calling at his back ? If regarded only from the point of view of the precision of his measurements, the unskilled man may actually be worth quite as much—perhaps even more—than the graduate of scientific or technical schools. From another point of view, however, the latter is by far the superior, for he is capable of noting, as it occurs, any new phenomenon which may happen in

the course of his researches and has a precise end, if different from that sought for.

Had Auer left his analysis of the rare earths to an assistant he would not have had the opportunity of observing the exceptional incandescence of thoria. It is then a question of the nature of the research; certain studies do not hold the prospect of containing any new phenomena, as, for example, the daily analysis of the same iron-ores, and these, without hesitation, should be confided to unskilled workers. On the other hand, the study of unknown minerals of far-reaching possibilities should be done by a competent chemist.

In the carrying out of an experiment two essential rules must be followed. All the conditions of the experiment must be noted with the greatest care. Certain of these may seem at the moment to be without interest, but later it may be found that on account of the neglect to record certain observations all the conclusions bearing on the subjects studied cannot be drawn. This is another point on which F. W. Taylor laid particular emphasis and recommended with some insistence to the attention of young engineers. You have perhaps, for instance, measured the resistance to heat of a silica brick by relating its firing temperature to its chemical composition, but you have not noted either its density or porosity, which did not interest you at the moment of the experiment. Later you will perceive that the swelling due to the final transformation of the silica brings with it a considerable reduction in the resistance. Ignoring the state of the quartz, what inference could be drawn from a rapid measurement of the density, you can draw no conclusions at this stage from the work you have done.

A second rule not less essential is to constrain oneself to follow stringently the programme laid down. One may think to improve it in the course of the investigation, and without further thought the initial programme is abandoned. Soon one is working by chance without method. It is no longer possible for the toil to be fruitful. This change is particularly serious if the experiment is being carried out by an operator distinct from the supervisor of the studies, or he who has arranged the programme. Unaware of the new conditions of the experiment, he can draw no conclusions from the results obtained, the work has been entirely wasted. Yet this is very frequently the case; an assistant trusted with an experiment seeks to improve on it, being inspired by his personal experience to modify the programme which has been laid down for him, thinking, perhaps, thereby to obtain a more advantageous result. He is, however, careful not to say how he has obtained it. It is disorder, and disorder is always unproductive.

(6) *Conclusion. The Application and Control of Results.*

Once the experiment has been accomplished, a conclusion must be drawn. It nearly always consists in a relationship between the result sought for and the factors on which it depends. This result may be enunciated verbally and after a purely qualitative fashion. To obtain greater precision, one may translate this result into a geometric curve, or, further, one may in this case be interested in changing the variables. Instead of having as abscissæ the measurements which could be made direct, their logarithms or other simple function of these measurements could be taken. Wherever one may by doing this arrive at a curve which is as nearly as possible a straight line, there is an advantage in doing it, because the precision of the interpolations, and even more so of the extrapolations, is thereby much increased. Finally, it is necessary to choose such a scale for the abscissæ that the curve presented is inclined to them at an angle as nearly as possible of $45°$.

The employment of algebraic formulæ to unite certain quantities of the results facilitates the ulterior calculations, especially in relating them to the axioms of science. On account of the inevitable inaccuracies of measurement, it is possible to find a large number of algebraic formulæ which may equally well represent the results obtained. In the arbitrary choice of these functions they must be useful within the limits of their applicability; that is to say, a function must be selected which will not give an absurd result for *nil* or infinite values of any variable. For instance, if representing a quantity that one may believe without limit as light, one must never take a parabolic function which could reach a maximum or minimum incompatible with the nature of the phenomena to be represented.

The next point for consideration is the discussion of the degree of accuracy borne by the result obtained. It is first necessary to find the ratio of precision between the result and its different factors. Frequently this relationship can be expressed by means of a differential logarithm, showing the relative error of the result by means of a sum of relative errors for each measurement of an individual factor.

It becomes necessary here to distinguish between systematic and accidental errors and to remember that the former are generally by far the more important. Further, the anxiety which one professes for the correction of accidental errors is unnecessary. It is foolish to apply to industrial problems, as is sometimes done, the principle of squaring the remainders. To draw from several divergent measurements a value which represents the maximum guarantee

of exactitude, one usually takes the arithmetical mean of the results after having suppressed some among them judged less good than the others, partly because of the conditions under which the experiment was carried out, and partly because they were wide of the average. This is a bad habit. One should always take the probable result, obtained by placing the results in the order of their decreasing size and taking the central result of the list. The abnormal results placed at the extremities of the list vanish spontaneously without arbitrary choice in the matter.

Systematic errors are much more important and more difficult to get rid of, because, as a rule, one is not aware of them. They are allowed to exist only through ignorance of their presence. One of the most frequent causes of systematic error lies in the reduced scale on which one is obliged to effect most of the experiments. Factors dependent on the dimensions or time taken up by an operation have exerted their influence unperceived. One endeavours to be prepared for this source of error, in making certain semi-industrial experiments before the actual practical operations; that is to say, an experiment is made on a scale intermediate between that of the factory and that of the laboratory. This will permit the observation of factors which, unobserved on the small scale, can influence the result on the factory scale. It is a precaution which is always extremely useful; one is never infallible.

The third phase of the conclusion arrived at is in passing from the laboratory to actual factory application. The difficulty encountered here lies in the fact that during the laboratory experiment one is little or not at all influenced by the question of finance.

Experiments on a small scale are relatively inexpensive, the fuel expended is small, the primary materials are also few, and mechanical force is only slightly employed, if at all. In passing from the laboratory to the factory, processes must be combined so as to permit of their economical realisation. Although there may be a difference in the apparatus employed, the conditions of temperature, composition and speed found in the laboratory to be most advantageous must be maintained. Every resource of industrial experience must be put into play, and it is here that the engineer must supersede the experimentalist.

The Field of Application.

Having reached the conclusion of this study of the ways and means of scientific method, one may ask : When should the scientific method be employed ? A factory, it is often stated, is an instrument of production and not a laboratory for scientific research. Research

is a luxury that may pay in wealthy concerns, but is not to be thought of in small enterprises.

It is a fallacy; in all factories, be they ever so small, research is being carried through all day, whether it is desired or not.   Every moment new problems present themselves for solution, and the only question which one can ask is :   How is the research to be done ? Must one be content with trial and error or can the scientific method be employed ?   The output, the quality, and the possibility of profit all vary from day to day.   Why ?   On what day does not this question crop up ?   A customer complains of the quality of a delivery.   Does the fault actually exist ?   Can it be avoided ?   Or, again, a rival relieves you of your trade by a superiority in the quality of his production.   How can the quality of your production be improved ?   The general reply to these and other questions is to fall back only on experience and reason.   Would it not be better to make a methodical study of the question ?   Would not that be more economical ?   That, gentlemen, is the question that I wish to submit to your meditations.

XXV.—*Opaque and Coloured Glasses and Ceramic Glazes of the same Nature.*

By Albert Granger, D.Sc.

(Read at the joint session in Paris of the Society of Glass Technology and the Société des Ingenieurs Civils, July 2nd, 1923.)

(Translated by Donald Robertson, B.Sc.Tech.)

The first chemists who studied glass looked on it as a substance of definite composition.   Dumas, in his chemical researches, drew the conclusion that glass was a mixture of silicates, and later Benrath, basing his observations on the fact that the silica in glass normally bears a molecular relationship to the bases of three to one, thought that glass consisted of trisilicates.   Another chemist, Zulkowski, actually proposed fully developed formulæ to satisfy the chemical constitution of glass.

This conception of glass from a uniquely chemical point of view, whilst rendering certain incontestable services, led, on the other hand, to erroneous interpretations of certain phenomena, and hindered things from being viewed in their proper light.

From the time when the idea of a solid solution made its appearance another conception of glass could be visualised.

I think that many of the phenomena that can be observed in the preparation of vitreous bodies should be visualised with other eyes than those of a simple chemist, if a plausible explanation for them is to be found.

In examining from an impartial point of view, the glasses manufactured in the industry, and those glasses rather more specialised, utilised under the general name of glazes, appertaining to the ceramic industry, one is obliged to recognise that there are often two methods of perception by means of which the explanation of a phenomenon can be sought. These two explanations, furthermore, may sometimes become invalidated in practice.

When seeking an explanation of the phenomena occurring during the opalisation of glasses, one is led to suppose that at a certain stage an insoluble body is produced, which remains in suspension in the vitreous liquid. On pushing the reaction further, one may finally obtain a glass which is completely opaque.

Among the opacifying agents, the fluorides, fluorspar, and cryolite play an important part. With a certain charge, predetermined for a given glass, one may obtain an opaque glass on first pouring, but with a smaller quantity the same opacification is only obtained on reheating the glass.

The first explanations given to account for this phenomenon are widely different. There were chemists who would see in it a complicated chemical process. There had to be a reaction between the silica and fluorine with the formation of silicon fluoride; but, even then, how should this reaction produce opacity?

The following reactions were visualised successively:

(a) Formation of alumina without fluorine in a crystalline state in the glass.

(b) Formation of a sodium fluorsilicate with or without alumina.

(c) Formation of aluminium fluoride.

(d) Formation of occluded silicon fluoride.

(e) Formation of silica in a finely divided state.

(f) Separation of an earthy or alkaline-earthy fluoride on cooling.

Of these hypotheses, the separation of silica or alumina appears to be the most tenable.

This hypothesis does not require the production of silicon fluoride, although this product is obtained during the fusion of the glass: at the same time, one has the right to ask oneself if this production is not of a secondary character. The action of steam (coming principally from the hydrated materials of the batch) or the furnace

gases, acting on the fluoride, produce hydrofluoric acid, which reacts at the same time on the silica. It seems to the author that this phenomenon of opacification by fluor-products is not entirely the main cause of the possible disengagement of silicon fluoride. I consider this reaction as secondary.

In 1915, G. Smull, taking up this subject of study, drew analogous conclusions; he regarded opacification as the separation from solution of silica or alumina.* It is difficult at the moment to justify this assertion, but it seems to me to be without question that the opacification should be the result of a separation of solid material disseminated throughout the mass.

On preparing a glass containing only a very small amount of fluorine, one may obtain, with a good melt, a light amber glass. This glass, on being lightly reheated, becomes opacified, but on repeating this treatment of the sample it again becomes clear. An explanation of this has been sought for in declaring that a fluoride of sodium has been formed during the period of heating, and that there has been a return to the state of calcium fluoride on cooling.

I do not believe in the truth of this explanation, because it is in contradiction to the preceding facts. If the fluorine was present in the uncoloured melt as sodium fluoride, there should be no reason why it should not remain as such on reheating. I think, rather, that one should see in this a precipitation brought about by the mobility of the molecules under the temperature conditions. The precipitation which was hindered by the viscosity of the medium on cooling occurred freely on reheating, but when, on reheating, too high a temperature was obtained, then the precipitate was redissolved.

Further, opacification is a phenomenon the operation of which can be followed. I have observed, and others have noted the fact as well, that certain fluor-containing glasses when thoroughly melted are perfectly transparent. If one gathers a drop of this glass while molten, one may observe the glass congealing while still transparent. Then, as cooling proceeds, the opacification is suddenly produced. *The phenomenon takes place in a mass which is already solid.*

Opacification is not produced in ceramics by the same means, as a rule; the fluoride glazes are capricious enough in their results. It is probable that the duration of firing in a medium containing water vapour is of great importance : there is a loss of fluorine, as is shown by analysis. Then one has recourse to such materials as the oxides of the MO_2 type, particularly SnO_2. The anhydride, arsenious oxide, has been indicated as an exception.

* *J. Soc. Chem. Ind.*, 1915, **34**, 402.

It is difficult in glasses such as those of which the glazes are constituted to produce opacification by reheating, probably on account of the quantities brought into operation, but in boric acid and aluminous glasses, of which certain glazes are constituted, and the basis of which is silica, felspar, chalk, and boric acid, one may not be faced with considerations as complicated as in those glasses containing fluorspar or cryolite. There is a deposit of *something* in the glass, because the opacifying medium cannot remain in solution.

If we pass now to the coloured glasses we shall find analogous phenomena.

I shall restrict myself to those glasses coloured by the oxides of cobalt, of copper, and of manganese.

A cobalt glass is blue, a copper glass may be blue or green, and manganese will colour the glass grey-rose. I would note that the anhydrous salts of cobalt are blue, and that the hydrated salts and solutions are red. The cobalt glass has then the colour of its anhydrous salts. The colours of the copper and manganese glasses are those of the salts of copper and manganese.

To me, in cobalt glasses the cobalt is without doubt in combination. In porcelain ware, it exists in the same state. In stating opinions which concern the other glasses, however, I think one ought to be very careful. Copper glasses show a tendency to deposit the metallic copper. Indeed, I have had occasion to observe in the preparation of a large number of glasses of this order that on the sides of the pot there were deposits of the metal. One may suggest, by way of explanation, the reducing actions occurring during fusion, but this explanation is insufficient. On pouring the molten glass into a copper ingot mould one can observe that where, in contact with the metal, a rapid cooling takes place there is a deposition of copper. The same thing applies to the pincers when they are used for drawing out the glass. All these facts would seem to indicate that the glass contains metallic copper in solution. The copper would be transformed from the cupric to the cuprous oxide at high temperatures. During the cooling stages, the cuprous oxide would be retransformed to the cupric state with deposition of copper, which is precipitated throughout the mass.* The coloration of copper ruby glasses is the exaggeration of this phenomenon. In the copper rubies obtained in the ceramic industry, the chemical process would be of the same order, and the reducing conditions which are believed indispensable to the formation of copper reds would have no other object than that of preventing oxidation from

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* $2CuO \longrightarrow Cu_2O + O$ at high temperatures,
$Cu_2O \longrightarrow CuO + Cu$ on cooling.—TRANSLATOR.

taking place; and, further, in copper ruby melts, when the reducing conditions have been exaggerated, instead of getting fine ruby tints, chocolate shades of an unpleasing nature are obtained. So far as manganese is concerned, phenomena are to be observed which do not accord with the general acceptation of a manganese silicate. On substituting oxide of manganese in the proportion of 0·1 molecule for 0·1 molecule of lime in the composition of an ordinary glass, I obtained a glass which was barely coloured; on reheating, this glass became brown in colour. This fact is not surprising. The type of ware known as " écaille " of the Sèvres porcelain is obtained by this process. The dish is fired in the furnace and is then reheated in a muffle, where it takes on its tortoise-shell colour. The oxide of manganese behaves as if it were free. On addition to the preceding batch of a body which could act as a reducing agent, the glass obtained is only slightly coloured, and the colour does not appear on reheating.

. Turning now to the glasses coloured by selenium and by cadmium sulphide, I find phenomena of the same order, phenomena which can only be explained by the conception of glasses as being almost always solvents.

Some samples of selenium and sulphide of cadmium glasses are normal, the others present anomalies. A blue sample may give orange tints when reheated in the same way as the others, due to a poor melt having produced a size of particle incompatible with the normal coloration. These samples, which have the appearance of agate, are the result of successive reheating treatments during the manufacture of the sample.

One could multiply the instances wherein the reheating produced modifications of colour in the greater number of glasses, results which are without explanation from a purely chemical point of view.

As a result of all this, I think I have demonstrated that the old purely chemical conceptions which have been applied to glass and to glazes are totally insufficient; their retention as theories of primary importance cannot but hinder the discovery of the key to the transformations which take place. I think that some of the facts are a little disconcerting to the eyes of a chemist of the old school, but they demonstrate the necessity of looking upon all phenomena in the light of modern science. One must accept the idea of a solution in many of those cases wherein one formerly allowed the intervention of a compound, the actual existence of which was doubtful from the observed facts.

NATIONAL SÈVRES PORCELAIN FACTORY,
PARIS.

XXVI.—*Some   Remarks   on   Technical   Education addressed chiefly to Glass Manufacturers.*

By Prof. W. E. S. Turner, D.Sc.

I DO not know if the Institution the Seventh Annual Report of which is attached is still the only University department of its kind in the world.   Some time ago the writer did see reference to a Professor of Glass Technology in Mexico, whilst a year or two ago he also received a letter stating that a Department of Glass Technology was to be set up in India.   No similar progress, at any rate, has been made in Germany, although the establishment in July, 1922, of a German Society of Glass Technology which aims at encouraging all scientific effort in connection with glass may ultimately bear fruit in this direction.   In Belgium also a move has been made to establish certain courses on glass technology at the University of Charleroi.   In America, the establishment of a special Department still seems to hang fire, although the importance of the American glass industry fully warrants that such a step should have been taken long before now.

The outbreak of war, however, did for this country a service which might for a very long time have been. delayed under normal conditions.   Scientific training in glass technology up to an advanced stage is available in this country, and, as yet, nowhere else in the world.   It is a matter for which progressive glass manufacturers in this country are proud.

I should like to take the opportunity, however, of suggesting to a wider circle of glass manufacturers that any educational effort of this kind can only be successful if it is co-operative ; that they, in turn, can stimulate progress by giving preference to trained men when making appointments and to those of their workmen who have devoted time to self-improvement when posts of foremen, etc., become vacant.

Many glass manufacturers have definitely recognised that progress in the future must depend on the use of all the scientific resources available.   It needs to be pointed out, however, and continually emphasised, that researches alone cannot be utilised to their full unless there is a proper understanding of the fundamental principles underlying them.   The results of many researches are too often quite beyond the power of manufacturers to understand even when described with the minimum of technical language.   It has, indeed, seemed to the writer that unless teaching and instruction go hand

in hand with research the mere pursuit of research is like attempting to put the roof on a house before the foundations themselves are laid.

The industry, if it is to make progress, needs continually an influx of young life trained to know and understand the principles underlying the industry.

Two types of such men are at present being trained in this country. The first consists of young men who can attend the University for full-time courses, and in a previous article the writer has referred to them as the "future leaders of the industry." The other type is that of the workers in the industry who, week by week, are attending local centre courses in various places in Great Britain, namely, those indicated in the accompanying report. These men sacrifice a good deal of their leisure time and give up sport for the chance of studying and self-improvement. Their willingness to do so must be evidence first of all of character, and, secondly, of a desire to get on, and manufacturers ought to be the first to take advantage of the spirit so shown.

What I would like to suggest quite definitely is that manufacturers should decide that in future all appointments in the works should be made on the basis of efficiency and knowledge. Appointments to posts of responsibility from the ranks of workmen should be made like that of deputies in coal mines, to quote only one example, on the basis of some sort of test examination, either the examinations conducted in connection with the glass technology classes at the local centres, or tests carried out by persons adequately equipped to examine by conversation the applicant's ability. Such appointments, when available, should be advertised together with the fact that candidates will be submitted to examination.

It does not necessarily follow that a man who has attended courses of instruction always has the necessary personality for a more responsible post, but amongst those who are trained will be found many who combine both knowledge and personality.

If manufacturers would only decide to adopt such a method of making appointments, not only would study and self-improvement become more common amongst workers in the glass industry, but their reaction and reflection on the progress and conduct of the works operations would be very beneficial.

The Department of Glass Technology at Sheffield would be prepared to assist in any scheme for testing an applicant's suitability for a post.

The Annual Report of the Delegacy for Glass Research is as follows :—

THE SEVENTH ANNUAL REPORT OF THE DELEGACY FOR GLASS RESEARCH FOR THE YEAR ENDING JULY 31ST, 1923.

THE negotiations with the Glass Research Association to which reference was made in the introduction to last year's Report were brought to a satisfactory close at the end of 1922, and resulted in an arrangement whereby the Delegacy was to carry out an amount of work annually for the Glass Research Association so as to provide an income from that source of not less than £3,000 per annum.   Special arrangements were also made in regard to the large-scale recuperative furnace which the Delegacy agreed to put into good working order and to permit the Association to use under agreed terms for maintenance.   This furnace has during the year been equipped with an oil-firing system, the installation being made almost entirely by members of the departmental staff without hindering or holding up the normal activities of the Department.

In addition to the oil-firing system, slight additions to the equipment have been made in the mixing room and in partitioning off one part of the upper pot-room for use as a library.   Most of this work also has been done by the staff.

A special grant of £2,000 has been received from the Scientific and Industrial Research Department and has been credited to the Buildings Fund to reduce the heavy debt still existing on the purchase and equipment of the Darnall Road premises.   It is with much pleasure that the Delegacy has to record the continued support of the West Riding County Council in the renewal of its annual grant of £500, and, from each of the Yorkshire Manufacturers' Associations, namely, the Yorkshire Flint Glass Bottle Manufacturers' Association and the Yorkshire Glass Bottle Manufacturers' Association, grants of £250.   The Delegacy expresses its best thanks for these grants.

The Educational Work of the Department.

The educational work carried on in and from the Department has suffered by the trade depression.

There is no doubt, however, that the work done in connection with local centre courses would be stimulated greatly if it were possible to arrive at some regular and systematic arrangement with manufacturers by which the work of successful students would meet recognition.   The next most important advance must come from the employers, and it is hoped that steps will be taken to discuss and bring into operation some plan to this end.

The number of students taking courses during the day in the Department during 1922–23 was 9, classified as follows :—

Degree Students.

1st year	....	3
2nd ,,	....	1
3rd ,,	....	2

Diploma Students.

3rd ,,	....	2
Special Courses.	....	1
		9

All three candidates for the degree of B.Sc.Tech. were successful, as were also four out of five candidates for the Diploma in Glass Technology. Two former students of the Department obtained the degree of M.Sc.Tech.

Local centre courses were held at Alloa, Castleford, Glasgow, Lemington-on-Tyne, Morley, and Sheffield, that at Lemington representing a new centre. Considerable efforts were made to organise a class at Mexboro. In July a prospective class of 16 was registered, but the class did not materialise owing to the depressed condition of the trade and the scattering of some of the students, who sought work outside the district.

Altogether 94 students were enrolled at these Local Centre courses, comprising :—

68	....	1st Year.
12	....	2nd ,,
14	....	3rd ,,

At the end of the first year course, 20 candidates presented themselves for examination, 12 being successful, 2 with distinction. At the second year course examination 10 students were present, 5 passing, 1 with distinction. Seven candidates sat for the third year examination, 4 passing.

In addition, 1 student completed the courses in Physics and in Mathematics, qualifying for the full certificate in Glass Technology, and 2 others passed the first year course in Physics and Mathematics

The total enrolments since these classes were inaugurated in 1915 are :—

At Sheffield	....	152
At 12 other centres	....	692
Total	....	844

Work done for Manufacturers.

During the year 146 cases of inquiry were dealt with, classified as follows :—

(1) Inquiries and consultations involving no experimental work 71

(2) Examinations of raw materials and the investigation of problems arising during the manufacture of glass 72

(3) Determination of the physical properties of glass 3

The total number of cases dealt with since the opening of the Department is 1,128.

Some of the experimental work carried out has been of an extensive and important character, and the Department has good cause for congratulation that its services are more and more being called for.

Systematic Researches and Publications.

Of special note is the Directory for the British Glass Industry which was compiled by Mr. G. S. Duncan, edited by Prof. W. E. S. Turner, and published under the auspices of the Society of Glass Technology. This Directory brought together for the first time the names of all manufacturers in every branch connected with the glass industry, as also those of firms supplying every conceivable commodity or pieces of plant for these various manufacturers. The Directory has been much appreciated.

Four papers appeared during the year in the Bulletin of the Glass Research Association and several others were reported to that Association with a view to publication.

In addition to these, research has been in very active progress by other workers of the Department, the complete list of publications being as follows :—

" The Present Position of the Glass Industry in Czecho-Slovakia."
By W. E. S. Turner, D.Sc.   J. Soc. Glass Tech., 1922, **6**, 274.

" The Technical Training of Future Leaders for the Glass Industry."
By W. E. S. Turner, D.Sc.   J. Soc. Glass Tech., 1923, **7**, 46.

" The Year in Review in the World of Glass Technology."   By W. E. S. Turner, D.Sc.   J. Soc. Glass Tech., 1923, **7**, 132.

" Czecho-Slovakian Glass."   By W. E. S. Turner, D.Sc.   *European Commercial*, Vienna, September 23, 1922.

" Heat Resisting Glasses."   By W. E. S. Turner, D.Sc.   *J. Royal Soc. Arts*, 1923, **71**, 401.

" The Society of Glass Technology."   By W. E. S. Turner, D.Sc.
    J. American Ceramic Society, 1923, **6**, 181.

" Teaching and Research in Glass Technology at the Department
    of Glass Technology, University of Sheffield."   By W. E. S.
    Turner, D.Sc.   *J. American Ceramic Society*, 1923, **6**, 183.

" The Effect of Sulphates on the Melting, Working, and other
    properties of Potash Lead Oxide Glass."   By Constance M.
    Muirhead, B.Sc., Edith M. Firth, B.Sc., F. W. Hodkin, B.Sc.,
    M. Parkin, M.Sc., and W. E. S. Turner, D.Sc.   *Glass Research
    Association Bulletin*, No. 4, October 1922, 5.

" The Influence of Moisture on the Melting of Glass Batches."   By
    Edith M. Firth, B.Sc., F. W. Hodkin, B.Sc., M. Parkin, M.Sc.,
    and W. E. S. Turner, D.Sc.   *Glass Research Association
    Bulletin*, No. 5, December 1922, 33.

" The Composition of Lime suitable for Various Purposes in Glass
    Making."   By Violet Dimbleby, B.Sc., and W. E. S. Turner,
    D.Sc.   *J. Soc. Glass Tech.*, 1922, **6**, 221.

" The Density of Soda-Lime–Magnesia Glasses and some Observa-
    tions on the Calculation of Density."   By S. English, M.Sc.,
    and W. E. S. Turner, D.Sc.   *J. Soc. Glass Tech.*, 1922,
    6, 228.

" Some Observations on the Mixing of Glass Batches in Factories."
    By A. W. Dickenson, Violet Dimbleby, B.Sc., L. E. Norton,
    B.Sc.Tech., and W. E. S. Turner, D.Sc.   *J. Soc. Glass Tech.*,
    1922, **6**, 234.

" The Action of Water and Steam under Pressure on some Soda-
    Lime–Silicate Glasses."   By F. W. Hodkin, B.Sc., and W. E. S.
    Turner, D.Sc.   *J. Soc. Glass Tech.*, 1922, **6**, 291.

" An Examination of some Current Views on the Detection of
    Strain in Glass."   By S. English, M.Sc.   *J. Soc. Glass Tech.*,
    1923, **7**, 20.

" The Effect of Various Constituents on the Viscosity of Glass near
    its Annealing Temperature."   By S. English, M.Sc.   *J. Soc.
    Glass Tech.*, 1923, **7**, 25.

" A Study of the Melting and Working Properties of Boric Oxide
    Glasses, with Special Reference to the Sodium Borosilicates.'
    By Violet Dimbleby, B.Sc., F. W. Hodkin, B.Sc., M. Parkin,
    M.Sc., and W. E. S. Turner, D.Sc.   *J. Soc. Glass Tech.*, 1923,
    7, 57.

" The Influence of Boric Oxide on the Annealing Temperature of
    Borosilicate Glasses."   By S. English, M.Sc., and W. E. S.
    Turner, D.Sc.   *J. Soc. Glass Tech.*, 1923, **7**, 73.

" The Function of Arsenic in Glass."   By Edith M. Firth, B.Sc.,
    F. W. Hodkin, B.Sc., M. Parkin, M.Sc., and W. E. S. Turner,

GLASS DEPARTMENT.—Income and Expenditure Account for period 1st August, 1922 to 31st July, 1923.

	£	s.	d.		£	s.	d.
1922.—July 31st.				**1923.—July 31st.**			
To Balance forward.—Glass Dele-				By Grants:—			
gacy a/c ... £1,647 11 8				Government ...	50	0	0
less Lampworking School a/c 149 14 5				University ...	500	0	0
	1,497	17	3	West Riding County Council	500	0	0
				Yorks. Flint Glass Bottle			
1923.—July 31st.				Manufs'. Association ...	166	13	4
To Salaries ...	3,035	9	0	Yorks. Glass Bottle Manufs'.			
,, Laboratory Expenses ...	156	6	8	Association ...	16	13	4
,, Printing and Stationery	71	12	11				1,233 6 8
,, Postages ...	29	0	9				
,, Advertising	7	4	3	,, Special Grant from the Applied Science			
,, Examination Expenses	5	11	6	Department ...			1,461 14 9
,, Incidental Expenses	105	11	2	,, Students' Fees ...			174 14 4
,, Wages ...	659	12	7	,, Tests and Researches—			
,, Rates and Insurance	270	12	1	(a) General ...	739	11	0
,, Telephones	13	13	0	(b) Glass Research Association	1,803	14	8
,, Coal, Light, and Water	739	16	11				2,543 5 3
,, Cleaning	26	6	8				
,, Furniture and Fittings ...	153	10	5	,, Royalties ...			15 4 5
,, Plant and Tools ...	26	15	0	,, Breakage Receipts ...			1,596 5 8
,, Travelling Expenses ...	59	6	4	,, Balance forward ...			
,, Legal Charges ...	2	19	2				
,, Bank Interest and Commission	112	16	3				
,, Repairs ...	50	12	10				
	£7,024	14	9				£7,024 14 9
1923.—July 31st.							
To Balance forward...	1596	5	8				

D.Sc. *Glass Research Association Bulletin*, No. 6, August
1923, 5.

" The Influence of Water on the Rate of Melting, and the Working
of Lime-Soda Glass."   By Edith M. Firth, B.Sc., F. W. Hodkin,
B.Sc., M. Parkin, M.Sc., and W. E. S. Turner, D.Sc.   *Glass
Research Association Bulletin*, No. 6, August, 1923, 25.

" A Rapid Method of Testing the Durability of Glassware."   By
H. S. Blackmore, Violet Dimbleby, B.Sc., and W. E. S. Turner,
D.Sc.   *J. Soc. Glass Tech.*, 1923, **7**, 122.

" The Physical Properties of Boric Oxide Containing Glasses and
their Bearing on the General Problem of the Constitution of
Glass."   By S. English, M.Sc., and W. E. S. Turner, D.Sc.
J. Soc. Glass Tech., 1923, **7**, 155.

" The Analysis of Glasses Rich in Boric Oxide."   By Violet
Dimbleby, B.Sc., and W. E. S. Turner, D.Sc.   *J. Soc. Glass
Tech.*, 1923, **7**, 76.

" Directory for the British Glass Industry."   Compiled by G. S.
Duncan, M.A., B.Sc., edited by W. E. S. Turner, D.Sc.   384
pages.   Published by the Society of Glass Technology, March,
1923.

The Financial Position.

The Balance Sheet for the year ending July 31st is attached.
The adverse balance at the beginning of the year was £1,497 17s. 3d.,
and heavy additional loss was incurred due to the fact that during
several months of the year no researches were proceeding for the
Glass Research Association and no income therefore was received
from that source.   But for an unexpected and large non-recurrent
grant from the Applied Science Department of the University the
adverse balance at the end of the year would have been very heavy.
The full amount of the grants from the Yorkshire Manufacturers'
Associations does not appear in the present Balance Sheet, but
with a continuation of the generous help of these Associations, the
position in 1923–24 ought to be considerably improved.   The actual
expenditure falls within that estimated for at the beginning of the
financial year and a number of economies have been effected.

XXVII.—*The Estimation of Selenium in Glass.*

By A. COUSEN, B.Sc., A.R.C.S., A.I.C.

(*Read at the Sheffield Meeting, Oct.* 17, 1923.)

IN the course of a detailed study of the use of selenium as a decolor-
ising agent in glass, it was found desirable to estimate, if possible,
the amount of selenium actually remaining in the glass.   It will be

seen that the problem is fraught with no little difficulty, since the amount of the element used for this purpose is exceedingly small. Thus, for instance, the proportion of selenium in the glass batch used for melting colourless glass in tank furnaces usually approximates to half an ounce to each 1,000 lb. of sand, which would result in a glass containing about 0·0024 per cent. of the element, providing that no losses occurred. That all the selenium remains in the glass is a most improbable contingency, since selenium is a somewhat volatile substance, having a boiling point, at atmospheric pressure, of 680°. It is evident, then, that the amount to be estimated will be something less than 0·0024 gm. per 100 gm. of glass, and probably considerably less.

Although there are many good methods for the estimation of selenium when it occurs in the free state or in the form of its more common compounds, one method only has been described, and that but in outline, for the estimation of small amounts of selenium occurring in glass. It is the method worked out by Fränkel *, and was employed for the determination of the element in ruby glass, in which it actually remained to the extent of 0·02 per cent., or about ten times the proportion actually used for decolorising purposes. The process involves four independent operations, namely, (1) the breaking down of the glass, (2) the separation of the selenium from the products of combustion, (3) the solution of the element in the form of selenious acid, and (4) the estimation of the amount of selenium in solution. For breaking down the glass, Fränkel used a hydrofluoric–sulphuric acid mixture in which the selenium dissolved as it was liberated, since it is soluble in the latter acid. After the removal of insoluble matter, precipitation of the selenium was accomplished by means of sulphurous acid, after which the element was presumably filtered off. No indication of the method of redissolving the selenium was given (the entire description contained very few details of procedure), but the process employed was presumably that of oxidising with nitric acid, or aqua regia, or a mixture of hydrochloric acid and potassium chlorate. Finally, the selenious acid was estimated colorimetrically, after the method of Meyer and von Garn, by the addition of hydrochloric acid and potassium iodide to the solution, whereby selenium and iodine were quantitatively obtained according to the equation :

$$H_2SeO_3 + 4HI = Se + 2I_2 + 3H_2O.$$
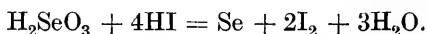
In the ordinary way, the selenium so precipitated rapidly coagulates and forms a turbid solution, but by the addition of gum arabic

* *Sprechsaal*, 1914, **47**, 444.

this coagulation is so delayed that the liquid remains clear for some time, and the amount of selenium present may be estimated by matching the combined selenium–iodine colour against that produced by a similarly-treated standard sodium selenite solution of approximately the same strength. This comparison Fränkel performed in a suitable colorimeter.

In attempting to employ the above method, several difficulties were encountered. In the first place, the separation of the selenium from the fluoride solution was found impracticable with the small amount of the element remaining in the glasses examined, a fact that will be more appreciated when it is stated that 10 gm. of the glass contained, in general, only about one-fifth of a milligram of selenium. It is evident that the simpler the process for separation the less likely is the loss to be, and the following modification of Fränkel's process was finally adopted. Ten gm. of finely powdered glass were carefully dissolved (in a platinum dish) in a mixture of 25 c.c. of concentrated hydrofluoric acid and 15 c.c. of water, the liquid being kept as cool as possible during the process, since continued heating results in the loss of appreciable amounts of selenium as fluoride. By this means, the liberated selenium remained in suspension, and it was allowed to stand for an hour or two in order to coagulate. The contents of the dish were then poured into 400 c.c. of boiling water, when all but the selenium dissolved. While the water was still hot the selenium was filtered off on to a thick pad of filter-paper pulp in a Gooch crucible attached to a filter-pump. In cases where it was suspected that some selenium from the glass might be dissolved as selenious acid, the original hydrofluoric acid solution of the glass was mixed with an equal bulk of hot concentrated hydrochloric acid and a current of sulphur dioxide passed.

The re-solution of the selenium was accomplished by dropping the paper pad into a beaker containing a mixture of 10 c.c. of water, 5 c.c. of hydrochloric acid, and not more than 3 or 4 c.c. of a very dilute solution of chlorine in water (of a strength approximately one-sixtieth normal). Despite the fact that the concentration of the chlorine was so small, it was only necessary to warm the liquid gently and to disintegrate the pulp with a glass rod in order to dissolve all the selenium from the pad.

A further difficulty in the process devised by Fränkel lies in removing chlorine from the solution of selenious acid. Chlorine itself liberates iodine from potassium iodide, and the presence of even traces of chlorine is sufficient to vitiate any results obtained. The usual method of removing chlorine from a selenious acid solution is by adding sodium chloride and then repeatedly evaporat-

ing the liquid to dryness on the steam-bath. A series of trials, using a very dilute solution of sodium selenite, proved that, however carefully this evaporation was performed, it resulted in losses of selenium, possibly carried away as the volatile chloride. These losses, although perhaps of small importance when larger quantities of selenium are to be estimated, are relatively great when the amount of the element used is of the order of less than a milligram, the whole of the selenium being lost when large amounts of chlorine are present, and no device was found by means of which such losses could be obviated.

It was then deemed advisable to attempt to estimate the selenium in the presence of chlorine, and since this could not be performed by the aid of potassium iodide, another precipitant was sought. One which proved very suitable was found in phenylhydrazine hydrochloride, which precipitated selenium slowly but completely from very dilute, cold solutions of selenious acid. The colour of the solution was not appreciably affected by the presence of chlorine, provided that the latter occurred only in very small amounts. Addition of gum arabic prevented the selenium, so released, from being precipitated, and a clear yellow solution was obtained. At the end of fifteen minutes the depth of colour had become constant and remained so over a considerable period of time. In order to test whether or not the depth of colour could be used as a measure of the amount of selenium in the solution the method employed was as follows :   .

A very dilute solution of sodium selenite containing 0·1 gm. of Na_2SeO_3 per litre was prepared and measured from a burette in successively increasing amounts of half a cubic centimetre into a series of Nessler tubes of approximately the same size and colour. To each tube was added 5 c.c. of hydrochloric acid, 1 c.c. of 5 per cent. gum arabic solution, and, after the solution had been made to 50 c.c., 5 c.c. of a half per cent. aqueous phenylhydrazine hydrochloride. The range of tints was found to vary regularly, and it was found possible, by taking a fresh Nessler tube containing an unknown amount of the standard solution of any value up to about 10 c.c., and treating it similarly to the standard tubes, to determine the amount of selenium present. The method was obviously correct to a half a cubic centimetre of the standard, that is, to 0·000023 gm., and matching was performed by moving the tube containing the unknown solution along the line of standard tubes until the one most nearly corresponding in colour was obtained. It was this modification of the colorimetric process which was finally adopted.

As it was obviously impossible to obtain a glass containing a

known amount of selenium in order to test the above method of estimation, synthetic mixtures of soda-lime glasses and pure selenium were at first employed. It was found, however, that even when the selenium was finely ground, it was still too coarse to be easily attacked by the dilute chlorine solution, whereas when precipitated from the glass its state of division is so fine that it allows of easy solution. A more comparable condition was obtained by measuring out a known amount of the standard sodium selenite solution into a platinum dish, adding hydrochloric acid, heating, and passing sulphur dioxide. To the precipitate of finely divided selenium in suspension were added 25 c.c. of hydrofluoric acid, and 10 gm. of a soda–lime glass which dissolved in the acid solution. The resultant liquid was washed into 400 c.c. of boiling water, and filtered on a pulp pad as before described. The selenium so separated was dissolved by the dilute chlorine solution, and the selenious acid solution freed from paper pulp by filtration. The filtrate and washings were collected in a Nessler tube, gum arabic was added and phenylhydrazine hydrochloride, the colour being finally matched against that of a series of tubes containing the standard solution in half cubic centimetre steps.

The results obtained were, in general, somewhat low, probably due to minute traces of selenium escaping either filtration or attack by the chlorine. The values were, however, within less than 1 c.c. of the actual amounts used, and as a general rule the loss was about a half a cubic centimetre, or the equivalent of 0·000023 gm. of selenium. The following table illustrates the degree of accuracy obtained :

Standard sol. used in test.	Standard to which test corresponded.	Standard sol. used in test.	Standard to which test corresponded.
2 c.c.	1·5—2·0 c.c.	4 c.c.	3·5 c.c.
3 ,,	2·0—2·5 ,,	5 ,,	4·5 ,,
3 ,,	2·5 ,,	7 ,,	6·5 ,,
4 ,,	3·5—4·0 ,,	8 ,,	7·5—8·0 ,,

A commercial glass decolorised by selenium in amount sufficient to give 0·0025 per cent. in the glass provided no volatilisation occurred was analysed by the above method. It was found necessary to use 20 gm. of the sample to obtain suitable readings, and two successive determinations each gave values of 2·5 c.c. of the standard selenite solution, corresponding with 0·00057 per cent. of selenium in the glass, or only about a quarter of the amount originally employed.

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DISCUSSION.

PROF. W. E. S. TURNER expressed the thanks of the Society to Mr. Cousen for the concentrated purpose with which he had pursued the question of determining the amount of selenium in glass. Some of the members might remember that the necessity for this work had arisen out of a paper presented in connection with the decolouring of glass by selenium. He and Mr. Cousen felt that they must, in order to arrive at any satisfactory conclusions, try to find how much selenium was left in the glass after the melting had taken place. For some considerable time Mr. Cousen had been at work on a method of estimation, and its application had led to results which would throw some very interesting light on the behaviour of selenium during glass-making. These results, however, would form a subject for future reference. In expressing their thanks to Mr. Cousen, Prof. Turner said members would scarcely realise the amount of time needed in order to arrive at what seemed so very simple a result.

MR. W. J. REES thought the method followed by the author certainly seemed one that would be extremely useful to the works chemist in determining the proportion of selenium present in glass. He asked if the author had at any time made any attempt to determine the presence of selenium, if the amount was very small, by a spectrographic method. Some years ago, Pollock, working in Dublin, attempted to devise a quantitative method, using a quartz spectrograph, and showed that as the concentration of the particular element looked for decreased, certain lines in the spectrum disappeared and there was the possibility of arriving at a quantitative method on this basis. If work in that direction could be pursued, it was just possible that a much quicker method of determination than the ordinary chemical method might be brought about. The chemist, of course, always liked to base his determinations on something he could see. A spectrographic method, if accurate, would be very much quicker.

MR. J. H. DAVIDSON said he had spent quite a lot of time estimating the amount of selenium in glass, and he would like to say how very grateful he was to Mr. Cousen for the extraordinary perseverance he had shown in his investigations. He could understand what difficulties he must have had to face and the paper struck him as being a good piece of work.

MR. J. R. CLARKE suggested a physical method of determining the amount of selenium, which, he said, was probably in a colloidal state. The conductivity of the selenium altered under the influence of light. It might, he thought, be possible to estimate the amount

of selenium in glass without breaking up the latter, by determining its conductivity, both in the dark and also under the influence of light.   The conductivity would probably be increased in proportion to the amount of selenium present and thus serve as a measure for determination.

Mr. A. Cousen, in replying, thanked those who had spoken for their appreciation of the work done.   It had taken rather a long time, but he thought the result was quite worth the effort.

With regard to Mr. Rees's suggestion that a spectrographic method might be used, they had had that in mind as a method of estimating selenium in glass, and it would be worth while comparing results by the two methods, but he doubted if the spectrographic method would be more rapid.   As a matter of fact, selenium could be estimated in glass chemically in a few hours.   On the other hand, the spectrographic method would involve the use of a costly and rare piece of apparatus, so that such a method could not be used in a general way.   The method of conductivity, he thought, seemed possible and it might be worth while also to compare the results obtained with actual chemical results.   Such a method, however, would be likely to be largely affected by the other substances present, which in a chemical method were entirely removed.

Mr. W. J. Rees suggested that the spectrographic method could be performed in about ten minutes.

XXVIII.—*The Production of Colourless Glass in Tank Furnaces with Special Reference to the Use of Selenium.   Part II.*

By A. Cousen, B.Sc., and W. E. S. Turner, D.Sc.

In the previous paper dealing with the subject,[*] the results of the study of the decolorising of a typical commercial soda–lime–silicate glass by means of selenium were presented.   It was then shown that there is a definite limit of iron oxide content in the glass which is capable of being satisfactorily decolorised either by the use of selenium or of sodium selenite, and this limit is about 0·09 per cent. The action of the selenium itself is subjected to a number of influences depending on the precise composition of the batch, and a number of other conditions.   Thus, it was found that salt-cake, which is usually present in small amounts in batches to be melted in tank

* This Journal, Trans. 1922, **6**, 168.

furnaces, makes it necessary to add distinctly more selenium or sodium selenite than when soda ash alone constitutes the source of alkali.   One reason for this increased need of selenium in such circumstances was shown to be due to the somewhat greater corrosive action of batches containing salt-cake on the fireclay of the container, leading to an increase in the iron oxide content of the glass.   Whilst, however, this increase of iron oxide content would necessitate the presence of a larger amount of selenium for decolorising, the explanation given could not cover all the influences at work, for it was shown that even when the resulting glasses contained the same amount of iron oxide more selenium was needed in the salt-cake batches than in the simple soda ash batches in order to produce the same degree of decolorising.

Some difference was also noted between the action of the elementary selenium and sodium selenite.   Under the conditions of our experiments, the latter seemed to be far more effective than the former, and even as little as 1/32 oz. per 1,000 lb. of sand was found in one case to be sufficient for producing decolorised glass.

Amongst other results, it was found that when decolorising was carried out by selenium or sodium selenite alone, the resulting glass was not very susceptible to change of colour when reheated, only those samples which initially possessed a distinct colour due to excess of selenium showing any appreciable change.   The temperature at which such change took place was in the neighbourhood of the annealing temperature of the glass, namely, approximately 550°.

These results, although definitely established, did leave us in some cases in doubt as to the precise nature of the changes taking place when selenium was present.   Thus, the difference in action between selenium and sodium selenite obviously needed further study, whilst the action of salt-cake required further explanation. Moreover, in the production of this type of glass commercially, arsenious oxide is almost invariably added, and constitutes a factor the influence of which must be definitely ascertained.   A number of these points we have taken up in the extension of the investigation and, in addition, we have made a study of the effect of the presence of such substances as sodium nitrate and borax, which have previously received consideration in works practice, and concerning which opinions have been expressed as to the advantages or disadvantages of their presence.

One other important factor to which some study has been given is the effect of the period of heating in the melting furnace on the colour of the glass, and some interesting results have been obtained as the outcome of such tests.

The General Conditions of Experiment.

The general conditions were those observed in Part I of this investigation, the standard batch being composed of 100 parts of sand, 37 of soda ash, and 20 of limespar. Variations were made on this batch by the substitution of a small proportion of the soda ash by its equivalent either of salt-cake or of sodium nitrate, or again of borax.

The standard amount of selenium which we describe as one unit is 0·003 part by weight for every 100 parts of sand (equivalent to $\frac{1}{2}$ oz. per 1000 lb. of sand). Cobalt oxide was added in fixed amount, being 1/6 of the standard weight of selenium, namely, 0·0005.

The meltings were made in small crucibles and occupied from three to three and a half hours at a temperature, except where otherwise stated, of 1,370°—1,380°.

The Effect of the Percentage of Iron Oxide.

We have previously shown that the maximum amount of iron oxide which can be decolorised is 0·09 per cent. As the ratio of external pot surface to weight of glass, and therefore also the extensiveness of pot corrosion, increases the smaller the pot becomes, in consequence of the small scale on which our experiments were made, the amount of iron oxide found in a number of our meltings exceeded 0·09. We considered it desirable to reduce this amount by coating the surface with a layer of china clay in which 5 per cent. of felspar was incorporated. These new pots gave good service, and as a rule, after a three hours' melting, the iron oxide content of the finished glass, determined by analysis, was only in the neighbourhood of 0·04 to 0·06 and 0·09 per cent. after eight or nine hours. In a few cases the lining was pierced and larger amounts of iron oxide thus entered the glass. The results are indicated in Table I.

TABLE I.

Sample.	Duration of Melting.	Temperature.	Per cent. Fe_2O_3 content.	Colour.
167	3	1380°	0·04	Pale yellow
169	$3\frac{1}{4}$	1380—1400°	0·06	Yellow
218	3	1380°	0·05	Decolorised
229A	3	1400°	—	Pale yellow
233A	3	1380°	0·04	Decolorised
237A	3	1380—1400°	0·05	Very pale yellow

In all these cases one unit only of selenium was employed, and it is quite clear that in many cases, when the iron oxide can be kept well below 0·09 per cent., this amount of selenium is in excess of what

is needed and can be reduced. There are other circumstances affecting this percentage of selenium, as will be referred to in a later section.

The Effect of Arsenious Oxide.

The proportion of arsenious oxide added in commercial practice varies somewhat, but seldom exceeds 2—3 parts per 1,000 of sand. In our experiments we fixed on an amount 50 times the selenium standard, so that for each 100 of sand, 0·15 of arsenious oxide was added. This proportion was kept constant throughout the series of meltings and the influence of the variation in amount of this substance remains yet to be investigated.

For precise comparison, each melting was performed alongside that of the simple soda ash batch containing selenium, but no arsenious oxide. The effect of the arsenious oxide was quite decisive even in the three-hour melts, for it was found to prevent the production of the pale yellow colour which in practically every case developed in the arsenic-free glass. The figures in Table II all refer to three-hour melts, and samples bracketed together, one with, and the other without arsenic, were melted in the same furnace.

It will be seen that the iron oxide content of the glasses was quite low and the whole unit of selenium was excessive, so that in the absence of arsenic a yellow colour was developed. Even with two units of selenium, however, the glass was colourless in the presence of arsenic and only faintly pink when 4 units were added.

TABLE II.

Sample.	Units of Selenium.	Arsenious oxide per 100 of Sand.	Per cent. Fe_2O_3.	Colour.
$\left\{\begin{matrix}167\\168\end{matrix}\right.$	1 1	— 0·15	0·04 0·03	Pale yellow Decolorised
$\left\{\begin{matrix}169\\170\end{matrix}\right.$	1 1	— 0·15	0·06 0·04	Yellow Decolorised
$\left\{\begin{matrix}181\\182\end{matrix}\right.$	2 2	— 0·15	0·04 0·05	Dirty yellow Decolorised
$\left\{\begin{matrix}185\\187\end{matrix}\right.$	4 4	— —	0·06 0·05	Dirty brown Very faint pink

In the case of sodium selenite our previous difficulty was to add a sufficiently small quantity to prevent the formation of a yellow or brown tint. Arsenious oxide was found to make for stable conditions and the need for very fine adjustment was thereby removed. Decolorised glass was now successfully obtained even with 2 units of selenite, a result never found when the selenite alone was employed.

TABLE III.

Sample.	Units of Selenite.	Arsenious Oxide per 100 of Sand.	Per cent. Fe_2O_3.	Colour.
$\begin{cases}172 \\ 174\end{cases}$	$\frac{1}{2}$ $\frac{1}{2}$	0·15 —	0·06 0·05	Decolorised Deep yellow
$\begin{cases}193 \\ 194 \\ 195\end{cases}$	2 2 1	— 0·15 0·15	— $\left.\begin{array}{c}— \\ —\end{array}\right\}$	Yellow Decolorised

All the foregoing results go to prove that arsenious oxide is a valuable adjunct to selenium or sodium selenite. In its absence, decolorising becomes uncertain or even impossible, especially if the glass has to stand for a period in the furnace.

The nature of the action of the arsenious oxide is not yet clear. It has been assumed, hitherto, that it serves as a reducing agent, liberating the selenium from the form either of selenite or of selenate. As, when only one unit of selenium is present, there is fifty times its weight of arsenious oxide, clearly there should be much more than sufficient to reduce all selenite to selenium. We might reasonably expect, accordingly, that, when arsenious oxide is added, the liberated selenium would reveal itself by an excess of colour, whereas the reverse is the case. Exceedingly small amounts of sodium selenite gave a yellow or brown colour to the glass, due to selenium itself, but with arsenious oxide this colour was suppressed, even under long-continued heating (see p. 316). Analysis of the glass for arsenic showed that all of it was retained, not, however, as arsenite (As_2O_3) but as arsenate (As_2O_5).

The Effect of Sodium Nitrate.

It has hitherto been generally accepted that batches containing selenium must be kept free from nitrates. Such instructions, for example, were issued a few years ago with an American patent decoloriser "Raylux," the important constituent of which was selenium. Certainly we have been assured that in the production of selenium ruby glasses nitrates must be excluded. If the sole action of the nitrate is to oxidise selenium to selenite, the red colour or the yellow colour ought to be suppressed. It seemed of interest to us actually to make tests, and we accordingly did so by substituting a small portion of the soda ash by sodium nitrate. The "unit of sodium nitrate" referred to in the appended table (Table IV) corresponds to 1·6 parts of the nitrate, this quantity being the equivalent of 1 part of soda ash. Again, for comparison, batches containing soda ash only with selenium were melted simultaneously in the same furnace.

The time of melting was in all cases three hours and the temperature 1,380° (in the case of batch No. 256A, it was 1,370°).

TABLE IV.

Sample.	Units of NaNO₃.	Units of Selenium.	Colour.
221	—	1	Pale yellow
223	1	0·5	Deep yellow
224	1	0·25	Pale yellow
256A	1	1	Pale pink
260A	1	1	Yellow
257A	—	1	Pale yellow
217	4	2	Deep reddish-brown
218	—	1	Decolorised
219	1	1	Brownish-pink
220	4	1	,, ,,
279	—	2	Pale yellow
280	4	2	Yellowish-brown (deeper than 279)
281	4	4	Pronounced brown
282	4	6	Deep reddish-brown

The results were contrary to expectation. Instead of suppressing the colour due to selenium, a deeper shade was always obtained and even when $\frac{1}{4}$ or $\frac{1}{2}$ unit of selenium only was present, pale or deep yellow colours were obtained, whereas there was no colour in the absence of nitrate even with a whole unit of selenium present.

The reason for this result, it seems to us, must be considered as independent of any possible oxidising influence—even admitting this to take place—which is far from proved. The intensifying of the colour would appear to be due to the somewhat increased speed of melting as the result of the presence of the sodium nitrate, itself a substance of quite low melting point. As we shall show later, this explanation appeared to be correct; but even before a method for determining the residual selenium had been worked out, it seemed to us that loss of selenium by volatilisation would be prevented to a considerable degree when once a glaze had formed over the batch. Such glaze would be produced rapidly by the more readily melted sodium nitrate batch.

The Influence of Borax.

Borax has, in one or two instances brought to our attention, been added to the batch, partly in the belief of assisting the decolorising action. It does not exert either an oxidising or a reducing action, however, and its melting point, although 742° as compared with 853° for sodium carbonate, is much higher than that of sodium nitrate, namely, 308°. Whilst it has been regarded as a flux, it has been proved * that borax batches in many cases do not melt so

* Dimbleby, Hodkin, Parkin, and Turner, this vol., TRANS., p. 57.

readily as those containing the corresponding amount of alkaline oxide in the form of soda ash.

Tests were made with a batch which would give about 1 per cent. of B_2O_3 to the glass, namely :

	No. 283.	Nos. 285 and 286.
Sand	100	100
Soda ash	37	36·5
Borax (crystal)	—	3·8
Limespar	20	20

Two units of selenium were added in each case and the meltings carried out simultaneously at 1,380° for three hours. All three glasses yielded pale yellow glasses identical in colour, and it appeared that small amounts of borax are entirely without influence on the colour or decolorising effect of selenium as compared with soda ash.

The Effect of Prolonged Heating.

A. *With Soda Ash Batches.*—A number of meltings were made to determine whether any alteration in the colour of the glasses took place when allowed to stand in the molten condition for prolonged periods. For convenience, two fillings on of the batch were made at an interval of fifteen minutes, and small sample pourings of the glass were taken after three, five and a half, and eight and a half hours. The temperature during the first period of three hours was generally maintained at 1,380—1,400°; that during the succeeding periods being either 1,380° or in the neighbourhood of 1,300°. Table V gives the results of meltings from simple soda ash batches, from which the tendency of the colour to deepen to a brown or yellowish-brown on standing is clearly seen. It was evident that selenium alone could not be employed for decolorising purposes when the glass was required to stand for a prolonged period as in a tank furnace, since no decolorised glasses were obtained after a spell of more than three hours' standing. In each case only 1 unit of selenium was used.

The iron oxide content of the glass was not determined in all cases, but sufficient results were available to indicate that, as a rule, the one unit of selenium present was more than enough for decolorising, a pale yellow colour being usually developed even after three hours. With standing, the solution of more iron oxide might have been expected to counterbalance the excess of selenium. Instead, the yellow colour grew more pronounced with time, deepening to brown in most cases after $8\frac{1}{2}$ hours.

B. *With Batches containing Salt-cake.*—Comparison of the soda ash batch with a batch containing 1·37 parts of salt-cake, substituting one part of soda ash, was next carried out, the time and conditions

TABLE V.

	After three hours.			After five and a half hours.		
Sample.	Temp.	Per cent. Fe_2O_3.	Colour.	Temp.	Per cent. Fe_2O_3.	Colour.
229	1400°	—	Pale yellow	1400°	—	Yellow
233	1400	0·04	Decolorised	1300	—	Pale yellow
237	1390	0·05	Pale yellow	1320	—	Yellow
240	1390	—	,, ,,	1320	—	,,
245	1380	0·06	,, ,,	1300	—	,,
248	1380	—	,, ,,	1300	—	,,
249	1380	—	,, ,,	1380	—	,,
252	1380	—	,, ,,	1380	—	,,
253	1370	—	,, ,,	1380	—	,,
256	1380	0·05	,, ,,	1320	—	,,

After eight and a half hours.

Sample.	Temp.	Per cent. Fe_2O_3.	Colour.
229	1400°	—	Yellowish-brown
233	1300	0·09	Greenish-yellow
237	1320	0·09	,, ,,
240	1320	—	,, ,,
245	1300	0·10	Yellowish-brown
248	1300	0·08	,, ,,
249	1380	0·09	,, ,,
252	1380	0·09	,, ,,
253	1380	0·11	,, ,,
256	1320	0·08	,, ,,

being as with the soda ash batch melts.   Since, as shown in Part I, the salt-cake batches needed larger amounts of selenium for decolorising, 2 units of the element were employed.

Very different results were observed as compared with the soda ash batches.   After three hours, the glass was either decolorised or showed faintly yellow or pink.   With prolonged heating, there was a gradual transition, not towards a yellower or browner colour as with the soda ash batches, but quite definitely towards the green. Thus, the yellow or pink became decolorised or pale green after five and a half hours, and definitely green after eight and a half hours.   The green colours observed were those usually associated with iron oxide colouring, and the analyses confirmed this view. It would, therefore, appear that either selenium was slowly expelled on standing in these cases, or, that the amount retained even after three hours, was exceptionally small and readily masked when the iron oxide content became greater as pot corrosion continued.

C. *Soda Ash Batches containing Arsenious Oxide.*—Glasses were melted with selenium and arsenious oxide over eight and a half hour periods, Table VII stating the results.   Once again the beneficial influence of arsenious oxide is demonstrated in suppressing

the colour due to the selenium, although two units of the latter were employed.

TABLE VI.

		After three hours.			After five and a half hours.	
Sample.	Temp.	Per cent. Fe_2O_3.	Colour.	Temp.	Per cent. Fe_2O_3.	Colour.
226 *	1400°	0·05	Very faint pink	1380°	—	Decolorised
227 *	1400	0·05	,, ,,	1380	—	,,
230 *	1400	0·05	Decolorised	1400	—	Green
231 *	1400	—	,,	1400	—	,,
234 *	1380	—	Very faint yellow	1300	—	Faint green
235 *	1380	0·04	,, ,,	1300	—	Decolorised
238 *	1390	—	Decolorised	1320	—	Faint green
239 *	1390	0·04	Very faint yellow	1320	—	Decolorised
228 †	1400	0·05	Very faint pink	1380	—	,,
232 †	1400	—	Decolorised	1400	—	Very pale green
236 †	1380	—	Very faint yellow	1300	—	Decolorised

After eight and a half hours.

Sample.	Temp.	Per cent. Fe_2O_3.	Colour.
226 *	1380°	0·09	Very faint green
227 *	1380	0·10	,, ,,
230 *	1400	0·21	Deep green
231 *	1400	0·15	Fairly deep green
234 *	1300	0·11	Pale green
235 *	1300	0·08	Very faint green
238 *	1320	0·11	Pale green
239 *	1320	0·08	Very faint green
228 †	1380	0·11	,, ,,
232 †	1400	0·14	Green
236 †	1300	0·09	Very faint green

* Selenium batches.   † Sodium selenite batches.

TABLE VII.

		After three hours.			After five and a half hours.	
Sample.	Temp.	Per cent. Fe_2O_3.	Colour.	Temp.	Per cent. Fe_2O_3.	Colour.
255	1370°	0·04	Decolorised	1370°	—	Pale green
259	1380	0·05	,,	1300	—	Decolorised
263	1380	0·04	Very faint pink	1320	—	,,

After eight and a half hours.

Sample.	Temp.	Per cent. Fe_2O_3.	Colour.
255	1370°	0·12	Pale green
259	1300	0·08	Decolorised
263	1320	0·06	,,

D. *Batches containing Sodium Nitrate.*—The pink or brownish-pink colours obtained by the use of sodium nitrate were found to

deepen on prolonged heating in the same way that soda ash melts deepened, giving finally deep yellowish-brown glasses. In the melts summarised in Table VIII a batch containing only 1 unit of sodium nitrate and 1 unit of selenium was used; yet deep yellow colours were finally obtained, being apparently unaffected by the increasing iron oxide content.

TABLE VIII.

	After three hours.			After five and a half hours.		
Sample.	Temp.	Per cent. Fe_2O_3.	Colour.	Temp.	Per cent. Fe_2O_3.	Colour.
256	1370°	0·05	Pink	1370°	—	Yellowish-brown
260	1380	—	Pale yellow	1300	—	,, ,,

	After eight and a half hours.		
Sample.	Temp.	Per cent. Fe_2O_3.	Colour.
256	1370°	0·08	Deep yellowish-brown
260	1300	—	,, ,,

E. *Period Meltings to Compare the Action of Selenium and Sodium Selenite.*—The batches tested contained soda ash only. In previous tests, a short period of melting had always resulted in deeper colours being obtained with the sodium selenite.

Meltings for eight and a half hours were now made in order to discover if over a longer period sodium selenite would still be the more effective as a colouring agent. In the first series, two batches containing 1 unit of selenium were compared with two containing only $\frac{1}{8}$ of a unit of sodium selenite. At the end of three hours the selenite glasses were somewhat more deeply yellow in colour, but on further heating both sets developed in intensity and after eight and a half hours the selenium melts were a slightly deeper yellowish-brown. In the second set, in which 1 unit of selenium was compared with $\frac{1}{2}$ a unit of sodium selenite, the selenite melts were somewhat deeper after three hours, but at the end of eight and a half hours little difference in colour in the two sets of glasses could be observed. Clearly the difference between the action of the two is dependent on time of heating, and tends to be reduced to zero as the period of heating is prolonged.

The Amount of Selenium Retained in Glass.

It became more and more apparent as the investigation proceeded that our conclusions could be at best but conjectures in many cases unless we could determine the amount of selenium retained in the glass under different conditions of melting.

This determination of selenium in such exceedingly small amounts as come into question in the decolorising of glass does not appear previously to have been successfully accomplished.   It was arranged, therefore, that one of us should devote himself to a thorough investigation of the subject, and the result has been the method described in another paper.*

Using this method, 20 grams of the glass had to be employed in order to obtain a sufficient quantity of selenium for detection, as a glass produced from a batch containing 1 unit of selenium per 100 units of sand (that is, 0·003 gm. of selenium per 100 gm. of sand) would contain only 0·0023 per cent. of the element even if no loss whatever due to volatilisation occurred.

TABLE IX.

Soda Ash Glasses.

Sample.	Units of Selenium.	Time of heating (hrs.).	Colour.		Standard Sodium Selenite Equivalent of Selenium in Glass.	Per cent. Selenium Retained.
218	1	3	Practically decolorised		1·5	15
171	,,	3	Yellow		1·25	12·5
9	2	3	Brown and dark		2·5	12·5
257c	1	8½	Yellowish-brown		1·75	17·5
253c	,,	,,	,,	,,	1·25	12·5
237c	,,	,,	,,	,,	1·50	15·0
249c	,,	,,	,,	,,	1·25	12·5
252c	,,	,,	,,	,,	1·0	10·0

TABLE X.

Salt-cake Glasses.

Sample.	Units of Selenium.	Time of heating (hrs.).	Colour.	Standard Solution of Selenite Equivalent to Selenium in Glass.	Per cent. Selenium Retained.
238c	2	8½	Pale green	1·0	5·0
250c	,,	,,	Deep yellow	,,	,,
239a	,,	3½	Pale yellow	,,	,,
239c	,,	8½	Pale green	,,	,,

TABLE XI.

Arsenious Oxide Glasses.

Sample.	Units of Selenium.	Time of heating (hrs.).	Colour.	Standard Solution of Selenite Equivalent to Selenium in Glass.	Per cent. Selenium Retained.
259c	2	8½	Very pale green	3·0	15
263c	,,	,,	Decolorised	2·5	12·5
189	6	3	Pale pink	3·75	18·7
259a	2	,,	Decolorised	3·0	15

* This Journal, TRANS., p. 303.

TABLE XII.

Sodium Nitrate Glasses.

Sample.	Units of Selenium.	Time of heating (hrs.).	Colour.	Standard Solution of Selenite Equivalent to Selenium in Glass.	Per cent. Selenium Retained.
241	1	3	Brownish-pink	4·0	40
242	,,	,,	,, ,,	3·5	35

The selenium in the glass was estimated by comparison with a standard solution of sodium selenite equivalent to 0·000046 gm. of selenium per c.c. and on this basis a considerable number of glasses which have previously been described in this paper were analysed. Tables IX, X, XI and XII state the results. The analyses provide some most interesting results and at once throw light on a number of obscure points in the investigation.

It will be noted in the first place that the amount of selenium found is only a rather small fraction, in most cases, of that which was added, and would indicate very considerable loss by volatilisation. In a commercial glass melted in a large tank furnace we have also found that the amount retained was only 23 per cent. of the amount of selenium added. The glass from which it was produced contained both arsenious oxide and a very small percentage of salt-cake.

When we consider the different constituents of the batch we find considerable differences in the amount of selenium retained. The actual percentages are stated in the tables, and on comparison it becomes clear why the salt-cake-containg batches needed distinctly more selenium for decolorising than those containing soda ash alone. It was clearly due to the much greater volatilisation of selenium, leaving so small an amount behind as to be ineffective, under some conditions, for decolorising and being insufficient also to develop the yellow colour by prolonged heating. It was noticed in our own small scale meltings that the rise and fall of the batch during the melting process seemed to be rather more prolonged when salt-cake was present, a fact which would be favourable to the escape of selenium.

On the other hand, the function of the sodium nitrate is to retain a very considerably greater proportion of the selenium than is the case with batches containing soda ash alone, salt-cake, or arsenious oxide.

In order to confirm these results, a series of meltings for a period of three hours was carried out at 1,380°, using the following batches :

	Salt-cake Batches.	Arsenious Oxide Batches.	Sodium Nitrate Batches.
Sand	100	100	100
Limespar	20	20	20
Soda ash	35	37	33
Salt-cake.............	2·7	—	—
Arsenious oxide	—	0·15	—
Sodium nitrate	—	—	6·4

Two, 4, and 6 units of selenium were added in each case. The residual selenium in the glass was determined, the results being summarised in Table XIII.

TABLE XIII.

Sample.	Type of Batch.	Units of Selenium.	Colour.	Standard Solution of Selenite Equivalent to Selenium in Glass.	Per. cent. Selenium Retained.
275	Soda ash	2	Yellow	1·0	5·0
276	Salt-cake	,,	Green	<1·0	<5·0
277	,,	4	{ Green with faint yellow streaks }	<1·0	<2·5
278	,,	6	,, ,,	<1·0	<1·6
273	,,	4	Decolorised	<1·0	<2·5
268	Arsenious oxide	2	,,	1·50	7·5
284	,, ,,	4	Very faint pink	3·0	7·5
270	,, ,,	6	Faint pink	4·0	6·6
280	Sodium nitrate	2	Yellowish-brown	3·5	17·5
281	,, ,,	4	Deep brown	6·0	15
282	,, ,,	6	Very deep reddish-brown	8·0	13·3

Only one filling of batch was made in these tests, so that the selenium losses are not comparable with those of other meltings where the batch was charged on in two parts. We have found more selenium retained when two charges were added. The results are comparable amongst themselves, however, and once again the glasses from salt-cake batches contained least selenium, so small, indeed, that it was difficult to estimate, being equivalent to less than 1 c.c. of the standard sodium selenite solution. All that we can say, on account of the difficulty of the estimation, is that less than 1·66 per cent. of the added selenium was retained when 6 parts of selenium were present in the batch. Quite definite and readily determinable amounts were retained in glasses prepared from soda ash. Those containing arsenious oxide were somewhat similar, in so far as their selenium content is concerned, to the pure soda ash batches. When sodium nitrate was present, the amount retained was very considerably greater, as will be observed from the tables.

As the batch containing small amounts of sodium nitrate is the one most readily melted, the explanation we have previously suggested appears to be correct, namely, that volatilisation takes place readily until a glaze has formed over the surface of the batch

sufficient to imprison the selenium. The amount of selenium retained
will therefore be found in commercial practice to vary somewhat
with the method of charging the furnace. We should not expect,
for example, that where the batch is charged through a dog house,
such a big loss would occur from salt-cake-containing batches as
in our small pot experiments, but there is clear indication that the
procedures adopted in the factory will produce different results.
It does not appear, from a study of the tables, that maintaining
the glass over a prolonged period at high temperature results in
much further volatilisation. Thus, from Table IX it will be seen
that the residual selenium when using 1 unit in the batch was
equivalent to 1·25 to 1·5 c.c. of the standard sodium selenite solution
after the glass had been heated for a melting period of three hours,
and was very similar in amount in the glasses which had been main-
tained for eight and a half hours, the titration value varying in
these cases from 1·0 to 1·75 c.c. Evidence of like character was
forthcoming from some of the other data.

It would, therefore, appear that the development of the pink,
yellow, or brown colour is due partly to the presence or absence
of agents such as arsenious oxide, partly to the amount of selenium
retained during the initial melting process, and partly to the duration
of heating. The change of colour, indeed, appears to be somewhat
similar to the changes which occur with time in the case of several
colloidal suspensions. In the preparation of the gold ruby, the
colour may pass through a series of changes, and if overheated may
develop a brown colour. When selenium first dissolves in the glass,
it would seem to be in the colourless state and to pass through a
series of colour changes on maintenance at a high temperature in
somewhat similar manner to the annealing colours both of gold ruby
and of selenium ruby glasses. One would naturally expect that if
any considerable proportion of the selenium were present in the
glass either as selenite or selenate then on dissolving the glass in
hydrofluoric acid the solution would need treatment with sulphur
dioxide in order to reduce the selenite before the whole of the selenium
could be obtained for determination. In this connection, we would
say that in no case has this treatment with sulphur dioxide been
found to be necessary, and in a number of cases in which the solution
was divided into two parts, one of which was treated with sulphur
dioxide, no difference in the amount of selenium obtained was
observed.

We have not yet had the opportunity of making analyses of
glasses in which the decolorising agent was added initially as selenite,
but this point is one of interest, and we hope to give it attention as
the investigation is extended.

Summary.

(1) A very large number of small scale meltings have been made in further elucidation of the behaviour of selenium and sodium selenite during the decolorising of glasses prepared either from batches containing soda ash only, or with small additions of salt-cake, sodium nitrate, borax, or arsenious oxide.

(2) With batches containing soda ash only, $\frac{1}{2}$ oz. of selenium per 1,000 lb. of sand is more than sufficient to decolorise glass which contains only 0·04 to 0·06 per cent. of iron oxide, the glass becoming yellow as the result of the selenium excess.

(3) The presence of sodium nitrate does not prevent the liberation of selenium in glasses prepared from batches containing this salt, and they are coloured much more intensely yellow or brown than soda ash glasses under corresponding conditions.

(4) The development of a yellow or brown colour in glasses containing selenium or sodium selenite is dependent on the time of heating as well as on the amount of selenium present. With glasses prepared from soda ash batches or containing sodium nitrate, the yellow colour deepens to brown when the glass is maintained for a period of hours at temperatures between 1,380° and 1,300°. In batches containing salt-cake, however, the colour changes from yellow or pink to green, owing to the very small amount of selenium retained in these batches and to the natural increase of iron oxide content as the glass stands in contact with the fireclay.

(5) A small amount of borax equivalent to the yield of 1 per cent. of B_2O_3 in the glass was found to be without effect either on the amount of selenium retained or upon the colour of the glass as compared with pure soda ash batches only.

(6) Arsenious oxide in the proportion of 1·5 parts to 1,000 of sand prevented the yellowish-brown colour due to selenium, even when an excessive amount of the latter was added, and even also when the glass was maintained for a considerable period at 1,380—1,300°. Arsenious oxide is the only substance we have so far discovered which makes easy the decolorising of selenium-containing glasses and gives stability to the conditions.

(7) Analysis of the glasses for selenium showed that the greater part is lost by volatilisation, a commercial glass only retaining 23 per cent. of that added. Batches which contain sodium nitrate, being more readily fusible, retain considerably more selenium than those which produce glasses more slowly.

(8) The amount of selenium actually needed for the operation of decolorising appears to be exceedingly small.

(9) From indications so far obtained, it would appear that the

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selenium added to a batch does not become oxidised to selenite, but remains as selenium, its colour only being developed slowly as the result of continued heating. .

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XXIX.—*The Ashley Bottle Machine.   A Historical Note.*

By S. ENGLISH, M.Sc.

(*Read at the Leeds Meeting, June 20th,* 1923.)

THE data embodied in the following note were collected in order to place on record some details of the first serious attempt to make narrow-mouth bottles by mechanical means, and since this attempt was centred first at Knottingley, next at Leeds, and finally at Castleford, it seemed appropriate to read this record to a meeting assembled at Leeds.

When a stranger to the glass industry sees for the first time a modern automatic bottle-making machine at work, he marvels at the number of operations necessary, and performed mechanically. If the machine is not too complex for his understanding, and if he thinks over the matter any further, he probably draws the conclusion that such a machine is the product of gradual development extending over a large number of years.   To a certain extent such a conclusion is correct, but at the same time it is not quite true.

In the first place, the operation of the earliest bottle-making machines was not based on a mechanical copying of manual bottle-blowing, and could not therefore be said to be a gradual development from previous practice.   In the second place, the development of bottle-making machinery has extended over a period of only thirty-seven years, and it is a matter that may well cause surprise that within such a comparatively short time, the making of bottles has been changed from an entirely manual to a mechanical process, so much so that several different types of completely automatic bottle-making machines are now successfully operated.   In this respect, it is probable that the glass industry stands out from all other industries, and great credit must be given to the designers and builders of present-day machines.   At the same time, it is worth while looking at the pioneer machines to see to what extent they contributed to this abnormally rapid development, and also to what extent the ideas embodied in them were utilised in the development of other machines.
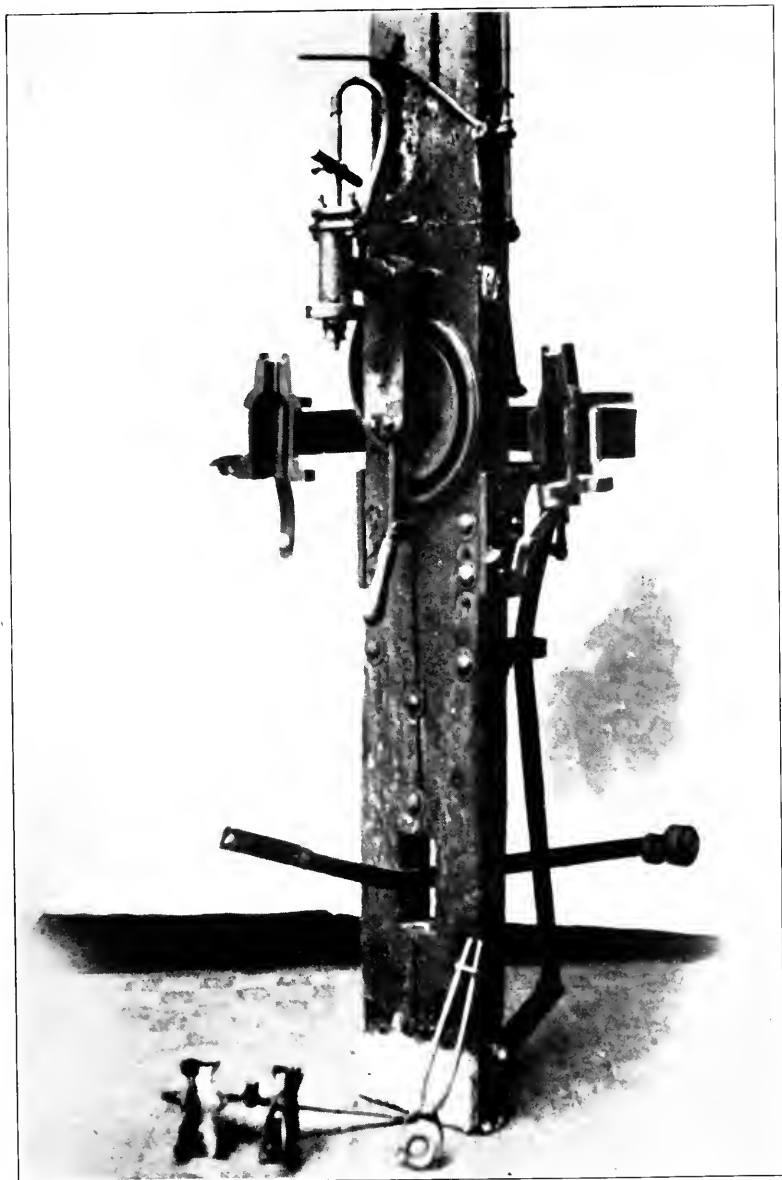
Fig. 1.

To one familiar only with modern glass-forming machines, it may be surprising to hear that the birthplace of bottle-making machinery is on this side of the Atlantic, but such is the case, and it was only after the possibility of making narrow-mouth bottles satisfactorily by machines had been proved in England that such bottle-making machinery was introduced into America.

The Plank and Pillar Machines.

The first machine to make narrow-mouth bottles was designed and built by H. M. Ashley, at Ferrybridge (Yorkshire), and it came to be developed in the following way. About 1866, the postmaster at Ferrybridge, Josiah Arnall, having in the course of his duties to go to the bottle works situated in his district, and seeing the way in which bottles were gathered, marvered, and blown, conceived an idea which he thought if developed would enable bottles to be blown by machinery. He submitted his idea to a prominent South Yorkshire bottle manufacturer (Mr. Edgar Breffitt), but apparently it was too crude or too revolutionary to be convincing. Nearly twenty years later, H. M. Ashley, the manager of an iron foundry in Ferrybridge, went to live with Arnall, and there can be no doubt that Arnall discussed with Ashley his ideas concerning the possibility of blowing bottles by mechanical means. As a result of such discussion, Ashley built an experimental machine * in which molten glass was poured into an inverted mould fitted with a plug to form the inside of the neck of the bottle, and with a sliding plunger fitting loosely into the body of the mould from its open end. When a charge of glass had been dropped into the mould, the sliding plunger was brought down on top of it, thus pressing it round about the neck-forming plug. Compressed air was then admitted through the plug, blowing up the bottle and at the same time raising the sliding plunger to the desired extent.

Such an arrangement was too crude to be successful, but it had sufficient good points to cause Ashley to try to develop it into a useful machine. The first step in its improvement appears to have been an appreciation of the fact that, instead of one mould, three distinct moulds were necessary; † one for forming the neck of the bottle, a second for giving a preliminary form to the main body of the glass, and a third for shaping the finished bottle. The functions of these three moulds corresponded to the distinct steps in the making of a bottle by hand, but the order in which the parts

* J. C. Arnall and H. M. Ashley : Brit. Pat., No. 8677, July 2nd, 1886.
† H. M. Ashley : Brit. Pat., No. 3434, March 7th, 1887.

of the bottle were made was reversed, the neck being made first instead of last.

This provision of a ring mould, parison mould, and blow mould was the foundation on which all Ashley's subsequent machines were built, and has been incorporated in every successful machine since. A machine with these features was built by Ashley at Ferrybridge,
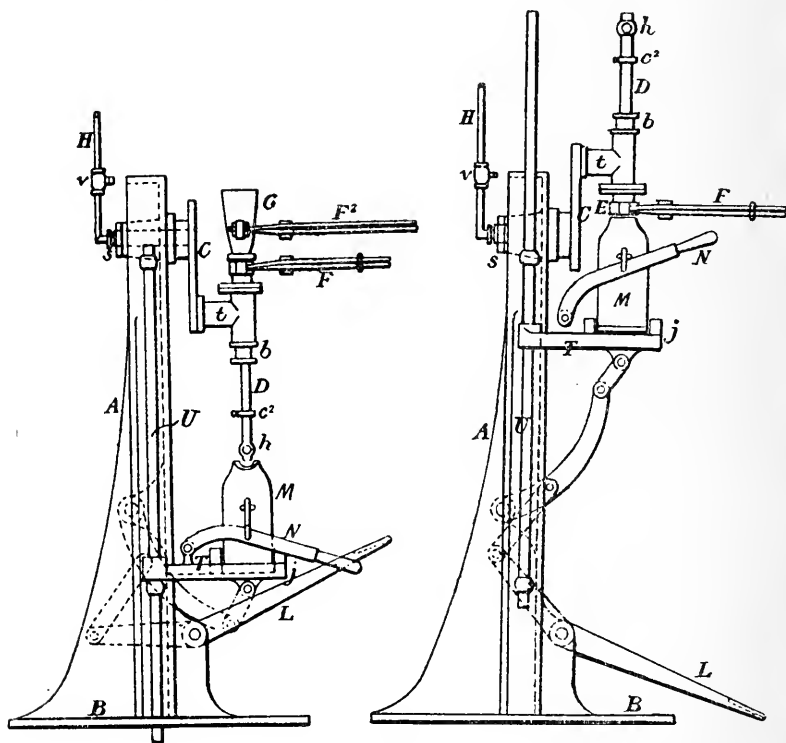
FIG. 2.

and was experimented with at Armley (Leeds) in 1886. It was then taken to Castleford for further trial and development. Fig. 1 is a photograph of this machine, and Fig. 2 shows side view drawings of a rather later machine of the same type.* Both figures show that it consisted of a rotatable head, C, fitted to an upright plank or pillar, and that through the head passed a punch, D, which also acted as a compressed air pipe. The parison, G, and ring moulds, E, were mounted on the ends of pairs of tongs, F, and were placed in position over the air nozzle and operated by hand. Molten glass

* H. M. Ashley : Brit. Pat., No. 3686 (1889), Nov. 10th, 1888.

was poured into the parison mould, and the plunger, D, was pressed upwards into the glass to form the neck, using the cross piece on the stem as a handle. After completing the neck, the plug was removed, and a slight puff of air was given from the pipe, H, and controlled by the valve, V. The parison mould halves were then opened and removed by hand, and the head carrying the blank by the ring mould was rotated until the glass was hanging vertically, in which position it was paddled by hand or allowed to extend according to requirements. The blow mould halves, at first mounted on arms hinged to a long lever, fulcrumed at the back of the plank, and operated by a foot pedal, were brought round the blank and secured together by a catch pin. The compressed air valve, V, was opened to complete the blowing of the bottle. Later, in the pillar machine (Fig. 2) the blow mould halves, M, were mounted on a rising table operated by a foot lever, L, and were closed by the lever, N. With such a machine, one gatherer fed two units and could make 130 dozen soda-water bottles per day of ten and a quarter hours. Since the output of this machine was not large, and its labour requirements were on the high side, it was not altogether satisfactory, but it must be admitted that it was a great step forward, as it proved the practicability of the proposal and the correctness of the ideas underlying its construction.

The Rotary Machines.

Ashley attempted to remedy the deficiencies in these single unit machines by designing a machine in which several bottles were in process of formation at one time, requiring only one gatherer and one blower. This machine * (Fig. 3), which was built in Sheffield, was of the rotary type, and had four parison moulds, m_2, four corresponding ring moulds, and one blow mould, m_2. The blowing heads, B and D, were mounted on arms at the circumference of a table, E, and were capable of inversion about a shaft, a. The ring moulds and parison moulds were hinged to the same arms that carried the blowing heads. Passing through each blow-head was a hollow plunger, P, which was normally held in the " out " position by a compressed spring. The mould table was rotated step by step at a pre-determined rate by means of the friction gearing, M. In the first position, glass was filled into the inverted parison mould, and then the intermittent rotation carried the table round one step. In doing so, a subsidiary table or framework, F, rotating with the main table, caused a sliding push rod to run up the fixed inclined plate, Q, thus forcing the plunger, P, into the soft glass

* H. M. Ashley, Brit. Pat., No. 3673, March 1st, 1889.

and forming the neck of the bottle. At the beginning of the next
step forward, the plunger was quickly withdrawn, the spring
keeping the push rod roller on the sharp decline, q, and at the
same time a puff of air was given to the blank. During the re-
mainder of this step of the rotation, the parison mould and blow-
head complete were inverted mechanically by the co-operation of
a fixed table, L, with a friction wheel, w, fixed on the axis, a, of
the crank arm carrying the blowhead, etc. Towards the end of
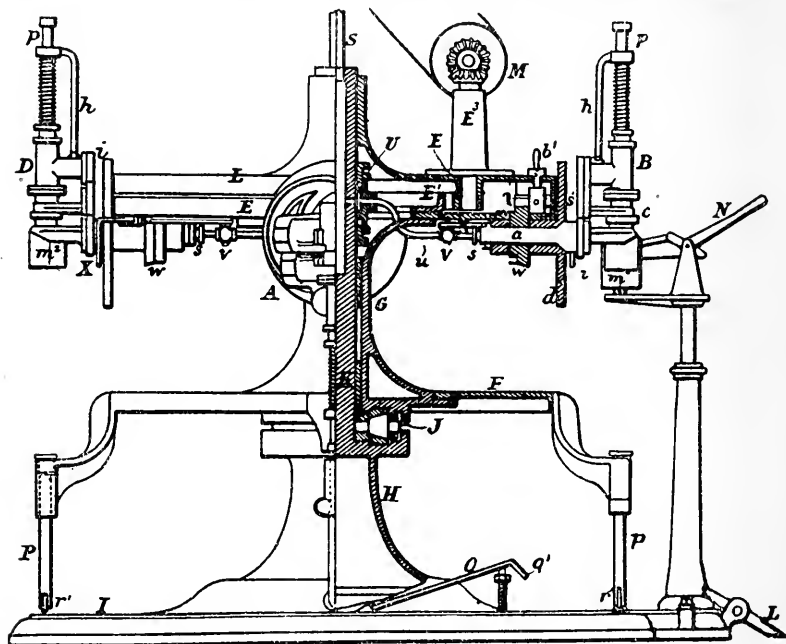
Fig. 3.

this inverting movement, the parison mould halves were opened
wide by means of eccentric gears attached to the fixed disc, d, and
the partly formed blank was left hanging freely from the ring
mould. The blow mould, which was mounted on an entirely
separate stand, was brought up and closed round the blank by
means of the levers, L' and N. Compressed air for blowing the
bottle was brought from the main, S, to a central distribution
box, and through the hollow shaft, a, to the blowhead and was
controlled by the valve, v. After the completion of the blowing
operation, the mould was opened by hand, and removed by re-
leasing the foot pedal, leaving the finished bottle hanging from
the ring mould. The third step of the intermittent rotation caused

slides to open the ring mould halves and allow the bottle to fall on to a suitable receptacle, after which the blow head and its attached parts were again mechanically inverted and the parison mould closed ready to receive another charge of glass.

This machine was not a success, but it only needed a few modifications to make somewhat similar machines work quite satisfactorily. In succeeding machines, the four units were replaced by three, and the inversion and opening of the parison moulds was done by compressed air operating a piston, as at the speed at which the machine was rotated the previous method was found to be too slow in its operation. The mechanical intermittent rotation was also dispensed with, and the bottle blower had to rotate the machine by hand to suit his rate of working. The single blow mould was retained, but it was mounted on a horizontal shaft and rocked into position; later (in 1892) a sliding blow mould table was used. At one time, Ashley had ten of these three head rotary machines at work at Castleford, each requiring only two men for its operation, and each capable of turning out 180 dozen bottles per day.

Unfortunately, Ashley carried the development of bottle-making machines no further, but from what has been said it is evident that these rotary machines contained practically all the elements from which modern machines have been developed. The principles embodied in most modern machines were first discovered and used in the various forms of these machines, and it is perhaps not too much to say that the success of certain types of machines in use at the present time is due to the fact that in principle they are the same as in Ashley's machines, but the details of the mechanisms are improved. When one remembers that Ashley was working in an entirely new and somewhat unpopular field, and had only his own resourcefulness to rely on, it must be admitted that these rotary machines, produced and working within five years of the taking out of his first patent, prove how extraordinarily successful he had been.

The Ashley (Machine Made) Bottle Co.

Having designed and built such a promising machine, it is somewhat surprising that Ashley's name has all but been forgotten in the glass industry, especially when one finds that those people who knew the Ashley machine say that it would compare favourably with some of those which are being worked satisfactorily to-day. In fact, there are now quite a number of machines working in South Yorkshire which are very similar indeed to the three-head rotary machines built by Ashley about 1890. One reason for the failure of the machine is to be found in the management of the company which was formed to exploit Ashley's patents.

The merits of the Ashley machine appear to have been recognised first by Mr. John Hardcastle (of Leeds), and it was through financial help from him that Ashley was able to complete his first machines. The patent rights for these machines were bought by Messrs. Sykes, MacVay, and the Codd Bottle Company of Castleford in 1887, but early in 1888 a new company, the Ashley (Machine Made) Bottle Company, was formed to take over these rights, including the works of Sykes, MacVay, and the Codd Bottle Company. In the prospectus, the promoters asserted that the Ashley machine could make bottles at one-tenth the labour cost by the hand method, and that the profit on the capacity of the Castleford works alone were estimated at £106,000 per annum, or more than 80 per cent. of the capital of the company. It was further estimated that at least £50,000 per annum would be received as royalties for patent licences, as manufacturers who had already seen the machines were most anxious to obtain licences immediately. On issuing the prospectus, the capital of the company was quickly over-subscribed and more than £6,500 had to be returned to the applicants for shares. During the time that negotiations for the formation of this company were proceeding a party of financiers and other interested people, including Press representatives, travelled from London to Castleford to see the machine in operation, and the following extracts from a report of this visit make interesting reading.

" GLASS BOTTLES.*

" *Sykes, MacVay & Company's New Process at Castleford.*

" Another familiar landmark is going. The glass bottle trade is in process of being melted down into new ' parisons ' without blowpipes and blowers, and instead of five men being necessary to evolve an imperial receptacle for beer or aërated water, it almost looks as if five innocently occupied adults might discover pastime in watching the conjoined labours of a machine and a youth in placing bottles at the service of good liquor as fast as they can be counted. . . . Never since the days of the Pharaohs has anything so clever in glass-making been devised, nor anything so simple. People may well ask, Why did not some one think of this expedient before ? but, carried to the test of a patent, nobody ever has. It has remained for a Yorkshireman, Mr. H. M. Ashley, of Ferrybridge, to revolutionise the trade, and as a legal assistant in this enterprise, he has secured patents in Germany, Austria, France, Belgium, the United States, Canada, and other countries likely to value cheap bottles. . . . Time was not lost in escorting . . . guests to the

* From the *Leeds Mercury,* December 17th, 1887.

shed where a humble beginning had been made in showing how a mould could be rendered obediently automatic with the assistance of a man and a boy, and as a measure of precaution, another man in addition. The conditions were not as perfect as they obviously will be when the mechanism is a full realisation of the inventor's ideas; but the merest novice standing by could see that the invention is equal to its task, and is a grand simplification of a much sub-divided and imperfect operation as carried out in its present form. It may be that the circular of invitation indulges in ' high falutin ' when it speaks of the idea as the ' most marvellous invention which has been brought out since the Bessemer steel process was introduced,' but it is a veritable stride in the ideas of mechanism. It appears that England has not been holding her ground in bottle-making. This is attributable solely to the higher wages paid for labour in England, . . . and the new apparatus which is to turn everything in our favour may be welcomed as a patriotic benefactor. The advantage now possible is certainly startling. It is stated that a gross of bottles, costing in labour by the present methods 3s. 10d. can now be manufactured at a labour cost of 3d. per gross. . . . Of all the tasks in giving a bottle shape none seems to have changed so little as that of blowing. The Egyptians blew, as we known from their pictures, so did the Greeks and Romans, and everybody down to this day, and the merit of Ashley's invention is that it blows pretty skilfully with automatic mechanism. . . . The new bottle-making machine steals a march on the blower—in fact, it gets several leagues ahead. It makes a bottle all in one continuous run. As shown yesterday, a little had to be left to the imagination, but only a little. The molten glass-supply is brought on the end of a rod to the mould, . . . and dropped into the neck mould first of all. The neck is made primarily in the new process—last in the old. Immediately upon falling into the neck mould a punch an inch or more in diameter rises and pushes up through the metal, the bottle appearing to rise in its formation. Then the punch sinks, and as it does so, a second interior punch rises and liberates a ring of air under gentle pressure. This has the effect of inflating the bottle. The position is then reversed, so that the air presses downward, and the envelope is both forced downward and falls naturally with gravitation. As soon as the droop is sufficient, the bottle is enclosed in a mould, full pressure of air is turned on and the bottle is completed. The advantage of this process lies in the perfection, uniformity, and rapidity of manufacture. There is no waste of metal, and no inequality in the thickness of the envelope. By mouth blowing it is impossible to render two bottles exactly alike, any more than two soap bubbles.

By the new process, it is not difficult to weigh the molten metal to a gram, and to inflate it to the full of the mould in quick succession.

" As the machine will be constructed, six, ten, or more moulds will be charged successively from a crucible of metal fresh from the furnace, and the air blowing will be automatic. A man between the furnace and the moulds will be sufficient, and two other hands will do the rest, including storage in the annealing chamber. A turntable will revolve the moulds for their supply of metal. In the centre of the table there will be a supply of air laid on, with branches to each of the bottle moulds.

" Average work affords this calculation. A furnace hole occupying five persons, produces seven gross of bottles per day, or thirty-five gross per week. The holes cost a little over 3s. 6d. per gross for labour. By the new system a hole will produce eighty gross per day at a cost of 3d. per gross for labour. In the works of Sykes & Co., sixty holes yield 420 gross per day, but the machine production will yield 4,800 gross per day, and that will give a saving of £780 on the estimated output. Besides the saving in labour, which may offset the present advantages of Belgium and Germany, there is an enormous saving in waste material. The present system wastes about 33 per cent. of the melting ; and although the material is used afterwards, there is a deterioration in quality from the use of the glass a second time."

In spite of the glowing prospects held out by the promoters of this company, and the undoubted advantages accruing from the use of this machine, the company does not seem to have prospered, and in November, 1890, a committee was appointed to report on its working and to find the reason for its lack of success. Extracts from this report which was issued in January, 1891, clearly indicate why the company had not made the profits which were anticipated in the prospectus, and make instructive reading. For example, the committee states : " Notwithstanding the sanguine statements in the prospectus, which were certainly calculated to lead subscribers to believe that the patent was then an ascertained success, it now appears that at the date of the formation of the company it was really in a completely experimental stage, no complete machine having then been made. . . . No licences for the use of the machine such as are referred to in the prospectus have been granted in connection with the patents, although several applications for licences have been received from other bottle-makers." In discussing the balance sheet presented in 1890, the report says : " The cost of production has been excessive, and this fact your committee believes to be attributable to

the lax management which has prevailed in carrying on the business of the company. The general laxity of management seems to have been increased by the division of the responsibility of the conduct of affairs between two managing directors and the mechanical engineer, who, your committee is led to understand, have not worked amicably together. The looseness of management seems to have been particularly apparent in the machine department, which your committee may here remark was only responsible for 13 per cent. of the good bottles turned out during the year ending 31st July, 1890, as against 87 per cent. made in the hand department. It would appear that early in 1888, soon after the formation of the company, the first four-mould machine was ordered from the Yorkshire Engine Company. Before this had been tested, three more similar machines were ordered from the same company. When these machines were delivered they were found to be un-workable, and now, the committee is informed, are worth perhaps £15 as old metal, although they cost nearly £1,100. Later on, a considerable number of single-mould machines were ordered from Mr. Horne, twenty-six in a completed state and five in parts, which were put together by the company's own mechanics. Of these machines, it would appear that eleven were sold to a foreign com-pany, and of the remainder only four are now working, the others having, your committee is informed, been cast aside, although it is believed that they might have been worked with advantage. . . . Your committee considers that the Ashley patent machines have never had a proper chance under the present management of developing their capabilities, and is surprised at the small progress which has been made since the formation of the company in the direction of such development. . . . It appears to your committee that if other makers can obtain profits, your company should be able to do so, while, with the machines under the control of a competent engineer, the profits should be considerably increased."

As a result of this report, a new board of directors was appointed with the view of improving the management of the company, but still the venture was not a financial success, and a meeting of shareholders was held in September, 1894, for the voluntary winding up and reconstruction of the company. There had been a loss of £2,500 on the year's working; of this £2,200 was said to have been lost through a prolonged coal strike, and the remainder due to foreign competition. In his speech at this meeting, the chair-man (Mr. A. Blackhouse), said : " The bottle machine never had fair play, and he was afraid it never would so long as the works were carried on at Castleford, where the union was in the very strongest position, and no bottle hand who was a member of the

union would either work himself, or allow his lads to assist in the working of any of the company's machines. They were therefore dependent on non-union labour, and very strong hostility was shown towards their men. When the men did their duty to the machine it worked exceedingly well. . . . The machine was the most valuable asset of the company, but the fact was that they had not sufficient capital to carry on their business. . . . It was a pity that this patent had ever been linked with such miserable works as those at Castleford."

After the reconstruction of the company, matters were not much improved, and as the result of an order given in the High Court of Justice by Mr. Justice Kekewich, on November 17th, 1894, the works of the company were sold by auction, the date of the sale being March 22nd, 1899. The bottle-making machines were bought up by Messrs. Bagley & Co., Knottingley, and Messrs. Cannington and Shaw, St. Helens.

In conclusion, I wish to acknowledge with grateful thanks the help which I have received in collecting together these notes; especially would I mention Mr. F. Sweeting who has supplied me with a photograph of the first Ashley machine and most of the old documents and reports from which the details of the Ashley Company have been obtained. I would also mention Mr. T. Jackson (Messrs. Jackson Bros., Knottingley), Mr. Pickard (Knottingley), one of Ashley's mechanics, and Mr. Ellis (Messrs. Bagley & Co., Knottingley) from whom I obtained details of the early history and development of Ashley's machine.

DEPARTMENT OF GLASS TECHNOLOGY,
    THE UNIVERSITY, SHEFFIELD.

XXX.—*A New Method of Glass Melting.*

By ALEXANDER FERGUSON.

THE ordinary tank furnace at present in vogue in the glass industry is by no means the ideal piece of plant for the preparation of glass. The heat which is supplied for melting purposes has to be distributed to such an extent that in general not more than 10 to 15 per cent. of the heat is absorbed in the actual production of the glass,

the remainder going off and disappearing from the huge surfaces by conductivity, radiation, and by other means.

There is here then presented a big field for improvement, and if this improvement can be effected by reduction of radiation and all round losses of heat, one simultaneously cuts down the cost of production, which is so heavy an item at the present time.

With these objects in view and based on considerable experience in the smelting of metals and melting of glass, the author has devised an entirely new scheme for melting and working glass in which all operations are intended to be automatical from the coal and batch bins to the warehouse counter.

Without allowing for the practical engineer's usual safety margin, he claims by following such a process, that 540 tons of finished glass per week could be produced at an expenditure of only 90 tons of fresh bituminous coal carbon, whereas in the best performance claimed at present in America no one has been able to produce 2 tons of glass per ton of coal.

The principle underlying the method, the subject of this paper, is to use the highest temperature at the stage where the heat absorption is greatest and then to utilise the waste heat to do the work requiring heat at gradually diminishing temperatures. In this scheme, air, oxygen, gas, batch, soda, and fuel would all be pre-heated to the permissible temperatures by waste gases only and at a temperature sufficient to supply the heat required. This obviates using the high temperatures during the earlier stages of heating up, and the intense heat is not spread over an enormous surface with its consequent enormous losses due to radiation.

In many square tanks, the author has seen radiation from high temperature outer walls when the inside temperature of 1400—1500° causing it was being used in considerable measure to do initial heating of the cool batch.

In the process I am advocating the main features are :—

(1) All the coal used should be first retorted to soft coke, then broken and delivered to the producer while still at a temperature of 400°.

(2) All the batch first pre-heated to just under 440°, and then elevated to the second pre-heater.

(3) The air pre-heated to nearly 500° and passed on to the re-cuperator to be raised to as nearly 1000° as can be obtained.

The heat required for these three processes would be ordinarily got by passing the waste heat and hot gas through the lehr.

(4) The CO_2 driven off in the second pre-heater is delivered to the incandescent zone of the producer at a temperature in excess

of 1050°, at which temperature 99·5 per cent. of it is converted to CO in presence of the carbon in the producer bed.

(5) The gas from the producer is raised to about 1000° by passage through the recuperator.

(6) The batch minus the soda is pre-heated to 1000° and the CO_2 is driven off, sucked out, and injected into the producer.

(7) The hot gas and air are burnt in a special conical-shaped melting chamber, using tangential burners to give a whirling flame at high velocity. Into this flame the finely divided batch and soda are charged from a spreader.

(8) The use of a special stream-line tank to hold the glass which comes from the funnel and to supply the forehearth, from which it is gathered by the gatherers.

(9) The combustion products pass from the tank and the waste heat is used under the pre-heater to heat up the batch and drive off the CO_2. They then pass down the recuperator, which they would leave at about 1000°, entering into the boiler to generate power. At about 550° they would pass from the boiler to the lehrs and pre-heaters, being exhausted at about 225° by a fan and being used for desiccation purposes until the temperature fell to about 100°.

The Plant.

Fig. 1 shows the melting chamber. Notice the shape of the funnel. Though not imperative, this shape is preferable since it gives ample room just where the gases are increased in volume by the heat and cool down as the heat is used up. According to a diagram given by Arndt, a glass of composition $SiO_2 72, Al_2O_3 3, CaO 5·5, K_2O 4·5, Na_2O 15$, would have a viscosity coefficient at 1400° of about 300. As the coefficient of viscosity of nitrogen, carbon dioxide, and air (at 20°) and water vapour (at 20·6°) are 0·000184, 0·00016, 0·00019 and 0·000097 C.G.S. units, respectively, and as the velocity of chemical action is dependent on the viscosity of the medium in which the reagents are present, it is clear that chemical action will take place much more quickly when the batch particles are surrounded by gas than when charged into viscous glass as in present-day tank practice.

The sand and lime having been already partly pre-heated by passing through a rabble conveyor similar to the coal retort, and over the lehr, to 400—450° by the waste heat from the recuperator, augmented by the heat of the glass bottles introduced into the closed lehr at about 600°, are elevated in a gas-tight elevator to the pre-heater chamber, in which it is constantly rabbled up and heated throughout over the exhaust gas from the tank. The

materials now enter the funnel by a down pipe fitted with a con-
tinually rotating blade mixer and spreader travelling at 160 to
220 r.p.m., which throws the finely-ground materials over the
sides of the vortex formed by the whirling gases. The sand and
lime meet the soda in the mixer, and when the alkali surrenders
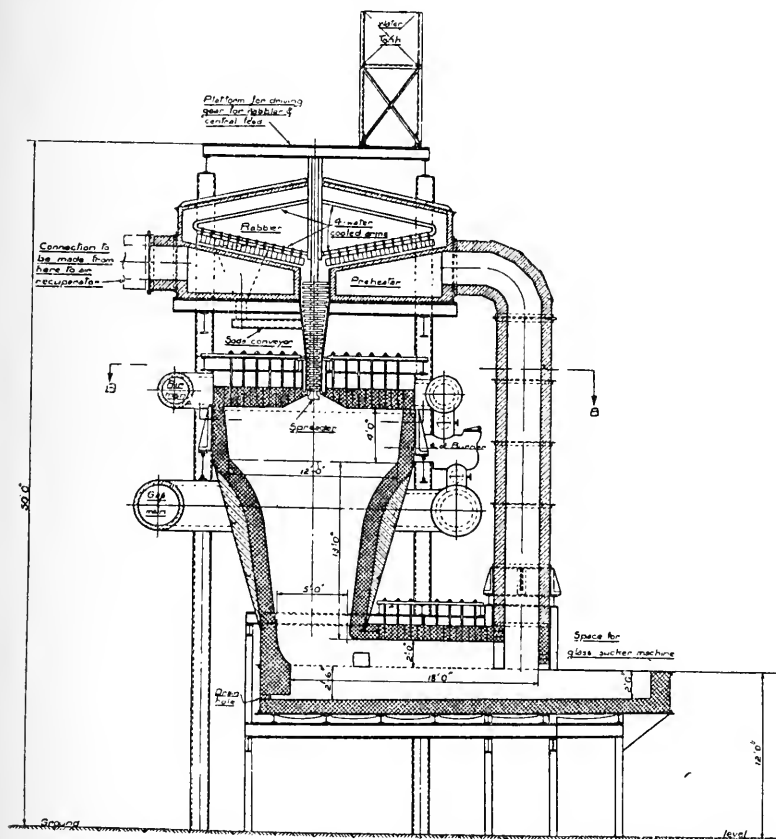
Section AA

FIG. 1.

its CO_2 the latter is drawn up by the vacuum sucker of the pre-
heater along with the CO_2 of the lime, and the gas is sent down
the pipe to the producer to become carbon monoxide.

Producing carbon monoxide in this way will reduce the amount
of air needed for the producer; hence also the proportion of nitrogen
which is useless for combustion. The liquid glass, melted in the
whirling flame, is cast out on to the sloping walls of the funnel,
down which it rolls like glucose. With an interior surface to the

funnel below the melting sphere of 301 square feet, I calculate that refined glass would fall into the tank at the rate of 2 lb. per second.

In regard to the fuel, my proposal is that the coal should pass from the bins through screw conveyors and entirely air-tight passages, crushers, and valves to the retort or continuous rabble forward-scrapers, over the escaping waste heat flues in the lehrs.

The moisture from the coal is first driven off, and with it goes generally any sulphur. There would be a change of state when
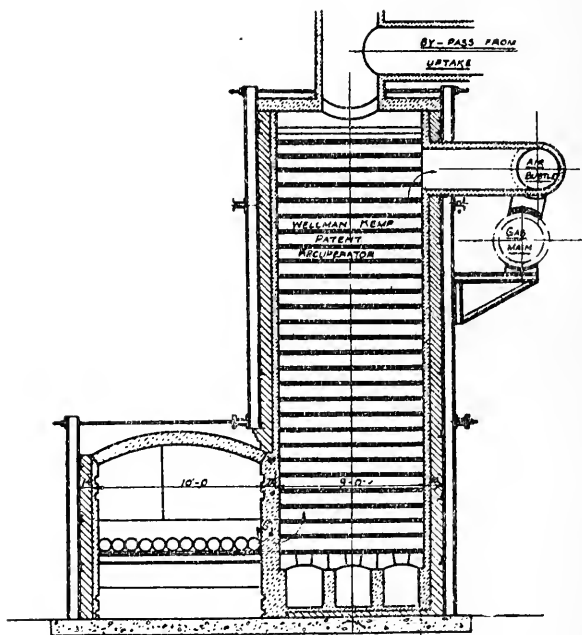
Fig. 2.

about half through the retort, and the coal would become quaggy and sticky, the hydrocarbons ethane, methane, and ethylene being sucked out as soon as freed, but the temperature of the retort would be kept low enough to keep in the tar and so deliver what is technically known as soft coke.

The soft coke would be passed through a breaker and valve into the fuel chamber of the producer. In the producer I have designed (Fig. 3), no coal dust can get into the gas flues, but all must pass through the coal-bed. The fuel chamber rakes the bed of coal and delivers the coal demanded (variable feed), stopping automatically any vents. The bed of coal is undisturbed until after combustion in

the incandescent zone, and the top of the grate revolves with the coal-bed. Below this mushroom top the grate bars are smooth, circular plates set at an angle of 45°, the air coming into the producer from under them and from the diffused air and steam being fed in. The producer is designed to gasify 20 to 30 cwt. of coal per hour.

When the gases escape out of the gas chamber of the producer they have to pass through a basket of quartz, and while still under the effect of kindling heat any dust possibly escaping is gasified,
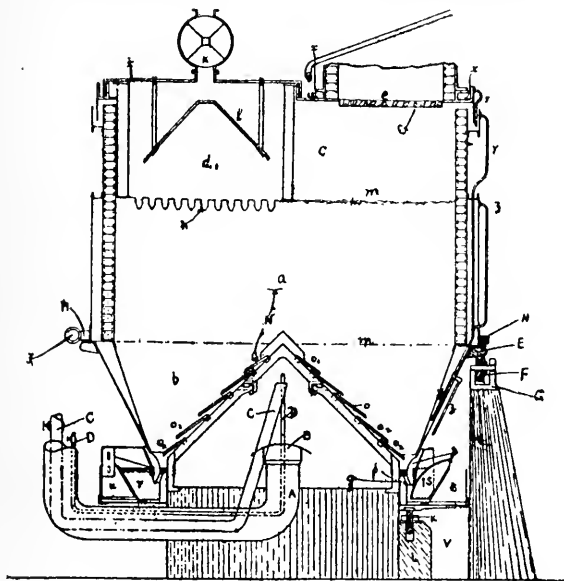
Fig. 3.

and further to rectify it fully the gas is driven against a very large baffle to cast down any unburnable dust carried up by the draught pressure.

The producer is 10 feet 6 inches internal diameter, with an ash zone 3 feet 6 inches (3 feet of which are fixed smooth plate grate), a coal-bed 3 feet 6 inches, and a gas chamber 3 feet, in which is fixed the fuel chamber. All parts except the top, the fuel chamber, and the inner teeth of the lower grate, and the gyratory ash crusher revolve.

The producer is water-jacketed throughout, behind fire bricks in the incandescent zone and behind steel plates in the ash zone, and part of the gas chamber. It is water-sealed top and bottom, having 6 inches water below, and 3 inches at the top. It is entirely

automatic throughout, filling continuously, and ash is dropped and removed beyond the producer into trucks for removal.

After leaving the baffle-box, the gas would be enriched with the hydrocarbons from the retort, and together pass to the burners. These are similar to many oil burners and have an injector central tube of compressed hot air surrounded by a spiral admitting and drawing in the gas with the additional pressure from the central tube. They are surrounded by an elongated outer reverse spiral admitting hot air. The two whirls, of gas and air, meet and mix thoroughly in a tube about 2 feet long, and pass from thence into the furnace. The pressure in the central pipe is such as to drive a current of hot air right through into the centre of the flame, preventing back firing and avoiding want of air.

In most tanks at present in use, the size is large in comparison with the weight of glass withdrawn daily. In my arrangement, the furnace is fitted with sloping siege or floor with a run-away closable port at the lower end under the funnel, and only holds from 20 to 22 tons of metal which, being refined when it falls into the tank, would require no more refining. This small quantity of metal could be quickly and easily run off at any time if needed.

The heat balance sheet for such a furnace is published in a paper read * before the Society of Engineers in which also is described the automatic machines for working out the glass.

* Advance proof. Meeting of Society of Engineers, Oct. 13th, 1923.

104 ADDISON GARDENS,
        LONDON, W. 14.

ABSTRACTS AND REVIEWS

NOTE.

1. The abstracts of British Patents are taken from the official abstracts in " Illustrated Official Journal (Patents)."

2. The fact that an abstract is given of a U.S.A. Patent Specification does not necessarily imply that there is no corresponding British Patent Specification.

I.—Glass-making Materials.

1. Dissociation of Calcium Sulphate at High Temperatures. P. P. BUDNIKOFF and J. K. SYRKEN (*Chem. Zeitung*, 1923, **47**, 22).—It was found desirable to investigate the dissociation of calcium sulphate above 800°. Below that temperature, allotropic modifications of gypsum occurred, but no decomposition. The following results were obtained :

Temp.	Duration of heating in hours.	Loss in weight.	Dissociation coefficient.	Percentage composition of residue.	
				CaSO₄.	CaO.
800°	8	0·14	0·0033	99·91	0·09
900	3	0·27	0·0045	99·81	0·19
1000	8	0·30	0·0051	99·79	0·21
1100	3	1·60	0·0272	98·86	1·14
1200	3	2·30	0·0391	98·35	1·65
1300	3	4·10	0·0697	97·00	3·00
1375	3	58·50	0·9946	1·33	98·67

W. S.

2. The Production and Sale of German Potash Salts in 1921. ANON. (*Chemische Industrie*, 1922, **45**, 177).—In 1921, the production amounted to 92,411,794 dz.* total weight or 10,668,487 dz. pure potash, compared with a total weight of 113,864,388 dz. in 1920 ; the reason given for the diminution was the difficulty of sale. Of the materials mined the following gave the manner of distribution :

Remaining as crude mineral ...	19,857,579 dz.	(2,638,202 dz. pure potash)				
,, ,, carnallite	2,621,752 ,,	(259,439 ,,	,,	,,	)	
Manure (18—22%)	3,290,813 ,,	(663,820 ,,	,,	,,	)	
,, (28—32%)	886,932 ,,	(269,779 ,,	,,	,,	)	
,, (38—42%)	7,523,122 ,,	(3,052,025 ,,	,,	,,	)	
Potassium chloride (50—60%)	3,544,355 ,,	(1,823,046 ,,	,,	,,	)	
,, ,, (above 60%)	776,558 ,,	(484,411 ,,	,,	,,	)	
Potassium sulphate (above 42% K₂O)	446,280 ,,	(220,641 ,,	,,	,,	)	
Potash magnesia	117,091 ,,	(32,037 ,,	,,	,,	)	

Very little was exported, but the proportion was better than in 1920, openings for trade having returned with America, Holland, Scandinavia, England, Austria, and Czecho-Slovakia in spite of adverse currency. W. S.

3. Iron Ore. (IMPERIAL MINERAL RESOURCES BUREAU, 1922, Part VI, Europe and Africa (Foreign), 275 pp. + 4 maps. Price 6s. net.) F. W. H.

4. Nickel (1913—1919). (IMPERIAL MINERAL RESOURCES BUREAU, 1922. The British Empire and Foreign Countries. 56 pp. Price 1s. 6d. net.) F. W. H.

* Equivalent to 50 kg.

II.—Glass : Manufacture and Properties.

5. Note on the Effect on Manganese in Glass Melted under Reduced Pressure. E. N. BUNTING (*J. Amer. Cer. Soc.*, 1922, **5**, 594).—When small pots of glass were refined in an electric furnace in which the pressure could be gradually reduced, the dissolved gases bubbled out, decomposable oxides were dissociated, and the finished glass assumed the ordinary light green colour, when cold, due to FeO. In an incomplete refining at a pressure of 0·03 atmosphere, the bottom 5 cm. of the glass were coloured light green, the middle 5 cm. colourless and the top 2 cm. pink. The green section was free from bubbles, the colourless section contained many fine ones, whilst the pink top contained more bubbles than glass. The manganese oxide content of the three layers was the same, namely, 0·20 per cent.

The author concluded that the decolorising action of manganese was destroyed by melting and refining glass at 1400° under a pressure of 0·03 atmosphere; the decolorising oxide, Mn_2O_3, was decomposed under these conditions into MnO and O_2; whilst the formation of the pink layer in the particular case cited was probably due to the high oxygen content of the gas in the bubbles which, before removal, oxidised sufficient MnO to Mn_2O_3 to colour the top layer pink.

In discussion, Bunting stated that in regard to arsenic, " all volatile constituents keep boiling out," and that the use of the vacuum effect was really a substitute for arsenic. The glass melted was a light flint, the batch containing nitre.

E. W. Tillotson suggested the possibility of the green colour being due to manganese in the form of manganate (MnO_3) and offered the following explanation of the observed phenomena : (1) The bottom portion was coloured green due to an excess of manganate (MnO_3); (2) in the middle portion a part of the green MnO_3 was dissociated to the complementary pink Mn_2O_3 so as to produce a " colourless " glass; (3) in the top layer, the dissociation had proceeded further, giving rise to an excess of Mn_2O_3 and a decided pink colour; (4) the bottom layer was free from bubbles, indicating no disengagement of oxygen, the colourless region contained a few bubbles, indicating that dissociation had commenced, and the top layer contained many bubbles, indicating a large disengagement of oxygen.

The author considered that Tillotson's explanation was probably incorrect for the following reasons : (1) Whilst the glass was being refined under reduced pressure the whole of the glass was full of bubbles and therefore it could not be said that there was no evolution of oxygen from the bottom layer; (2) similar meltings, where refining was more complete, were wholly coloured green. It appeared to him very improbable that, at a temperature of 1400°, in a vacuum, any MnO_3 would not have been reduced to MnO, as the dissociation temperature of MnO_3 was considerably below 1400°.   F. W. H.

6. Glass Containers (A Discussion) (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 343).—References were made to papers by A. W. Bitting (this Journal, ABS., 1922, 6, No. 14), A. E. Williams (*ibid.*, ABS., 1922, **6**, No. 328), and K. L. Ford (*ibid.*, ABS., 1922, **6**, No. 329). Attention was directed to the prevention of weathering of glass in storage and to the stability of glass towards various foodstuffs with which it came in contact. Carbon dioxide was considered by some speakers to produce fatigue in the glass. Bottles containing ginger ale, stored for six weeks, showed a much higher percentage breakage than originally, due presumably to the exposure for this period to high internal pressure of carbon dioxide. Milk bottles, it was stated, had an average life of three to eight trips, the high breakage being due to repeated sterilisation rather than through usage. No answer was vouchsafed to a question as to whether strained glass was more subject to weathering. The use of salt cake in glass batches was recommended as producing greater stability in the glass.　　　　　　　　　　　　　　　F. W. H.

7. Pyrex Glass. O. LECHER (*Chem. Zeitung*, 1922, **46**, 469).—The analytical composition of a sample of Pyrex glass was given as follows : SiO_2 80·71, B_2O_3 10·47, Al_2O_3 3·55, CaO 0·70, MgO 0·57, and Na_2O 4·14.　　　　　　　　　　　　　　F. W. H.

8. Synthetic Jewel Bearing. T. G. McDOUGAL and S. J. McDOWELL, both of Flint, Michigan. Assignors to CHAMPION IGNITION Co., Flint, Michigan, U.S.A. (U.S.A. Pat., December 12th, 1922, No. **1438188**. Original application filed January 14th, 1920, No. **357438**. Divided, and this application filed February 10th, 1922, No. **535647**). See this Journal, 1922, **6**, ABS., No. 321.　　　　　　　　　　　　　　　　　S. E.

9. Pyrex Glass as a Material for Chemical Plant Construction. A. E. MARSHALL (*J. Ind. Eng. Chem.*, 1923, **15**, 141).—The characteristic properties of pyrex glass rendered it specially suitable for certain parts of chemical plant hitherto constructed in porcelain, fused silica, or high silicon–iron alloys. Thus acid fume mains, cascade dishes, separatory funnels, and sight glasses had all been constructed satisfactorily. Breakages were stated to be less than with porcelain, as the transparency of the ware caused workmen to treat it as much more fragile than it really was. A factor fatal to cheap production was the very high proportion of " special " sizes differing only in unessentials from stock patterns.

A further field of utility was the use of pyrex glass as high tension electrical insulators. It was claimed that these had at least twice the mechanical strength of porcelain and were much easier to inspect for faults.　　　　　　　　　　　　　　　　M. P.

10. A Modified Glass Block for Pavement Lights, etc F. L. KEPPLER, 1799, First Avenue, New York, U.S.A. (Brit. Pat., **184655**, July 6th, 1921).—A square glass block, etc., for

partitions, pavements, skylights, etc., has a flat top, A, and down-wardly extending, flared walls which are corrugated to afford a
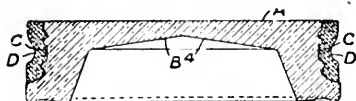
Fig. 1.

hold for cement. The inner face, B^4, of the hollow block is curved or inclined to prevent transparency, and the lower edge of the outer wall is thickened to facilitate complete annealing. A band of cement, C, is secured to the block when manufactured to facilitate setting of the added cement when building, a depression, D, being formed in the periphery.

H. G. C.

11. The Preparation of Eye-preserving Glass for Spectacles. W. CROOKES (*Phil. Trans. Roy. Soc.*, 1914, [*A*], **214**, 1).—The experiments were carried out in connection with the Glass Worker's Cataract Committee of the Royal Society. Photo-spectrographic and other examinations were first made of the radiation emitted from molten glass under working conditions. At the working end of the furnace, the temperature of which was estimated at 1200°, the radiation was found to be continuous from beyond λ 7800 to λ 4320. At the melting end, of temperature 1500°, the spectrum extended down to λ 3345. There were thus four requirements for eye-preserving glasses : they must absorb heat rays ; they must absorb ultra-violet rays ; the absorption of the luminous rays must be as uniform throughout the spectrum as possible, in order that the colour of objects examined shall not be distorted ; the intensity of the luminous rays must be reduced to prevent the sensation of glare.

To test the glasses produced for opacity to ultra-violet light, the source of light used was the light from a spark discharge between uranium poles superposed on that from a Nernst lamp. A continuous spectrum extending from λ 2000 to λ 8000 was thus obtained. The absorption of such a beam produced by flat plates 2 mm. thick was observed. To examine the infra-red transmission, the light was first filtered through biotite and then the transmission examined with the aid of a radiometer.

The basis for the preparation of the coloured glasses was a soda-lime batch of the following percentage composition : sand 61·00, sodium carbonate, anhydrous 25·50, sodium nitrate, recrystallised 5·00, calcium carbonate, precipitated 7·20, borax 0·75, arsenic trioxide 0·55. The oxides, or nitrates, of a large proportion of the number of known elements were fused up with this glass, and eventually those mentioned later were selected as being worthy of further examination.

Cerium was generally used in the form of nitrate, though occasionally as borate or oxide. A nearly colourless glass was produced which cut off the ultra-violet and transmitted the luminous spectrum. The heat absorption was about 30 per cent., and did not vary much with the amount of cerium present. Chromium, in quantities of less than 1 per cent. cut off the ultra-violet from λ 4550. In

larger quantities, the absorption extended up to λ 5600. With 1 per cent. Cr., 30 per cent. of the heat rays was absorbed. With 0·85 per cent., 37 per cent. of the total light was transmitted, the glass being green. Using cobalt and nickel, the former absorbed 40 per cent. of the heat, most of the light, and transmitted the ultra-violet rays below λ 3200. The latter coloured the glass brown. The two together produced a neutral grey tint, when the proportions were one part of cobalt to five of nickel.

Glass containing copper was coloured blue, absorbed 75 per cent. of the heat rays, and was nearly without effect on the ultra-violet. Iron in the ferrous state absorbed a large amount of the heat radiation. One per cent. of ferrous iron cut off 65 per cent., and 2·3 per cent. of iron cut off 89 per cent. of the heat rays. The action on the ultra-violet end was slight. Between 50 and 70 per cent. of luminous radiation was transmitted. The colour was greenish-blue.

Iron present in small proportions, such as 0·25 per cent., in the ferric state transmitted from λ 3500. When 2 per cent. was present the ultra-violet below λ 4000 and 63 per cent. of the total heat were absorbed. The colour was pure yellow, 75 per cent. of the incident light being transmitted.

Faraday's lead borosilicate glass was found to be opaque to the ultra-violet beyond λ 3800. It absorbed 38·5 per cent. of the heat radiation.

Manganese was used to neutralise the colour, whilst retaining the absorption properties, of greenish-coloured glasses.

Neodymium and praseodymium coloured the glass lilac and greenish-yellow, respectively. When used together in the proportions of one to five, a neutral grey glass was obtained. Uranium glasses became increasingly opaque to ultra-violet light as the quantity of uranium was increased. With 4 per cent. of uranium, the ultra-violet from λ 4500, and 55 per cent. of the heat radiation were absorbed.

Details were given of nineteen specially prepared glasses, which contained mixtures of the colouring agents mentioned, arranged in the following four tables : (1) Absorption of heat rays, (2) absorption of ultra-violet rays, (3) transmission of luminous rays, (4) reduction of glare. The absorption of the heat rays varied up to 98 per cent., but this glass (a very complex one) only transmitted 27·6 per cent. of the luminous radiation. For general purposes, including reduction of glare, a pale blue glass containing ferric iron, cobalt, and cerium was recommended. It absorbed 51 per cent. of the heat, transmitted 63 per cent. of the light, and absorbed the ultra-violet beyond λ 3550. The applicability of the various compositions to different purposes was discussed.

J. R. C.

12. The Use of Zirconium in the Preparation of White Enamels. P. P. BUDNIKOFF (*Zeitsch. angew. Chem.*, 1923, **36**, 8).—Shortage of tin and high prices had caused people to look for tin-free white glazes. Antimony, and arsenic oxides, and bone ash

had all been tried, but the use of zirconium as oxide, hydrate, or other compound seemed to hold out good prospects, and in fact when present up to 5 per cent. gave a quite white enamel, but a mixture of zirconium oxide and tin oxide was still better. When the zirconia was introduced into the glaze by grinding, although some beneficial results accrued, the melting point of the glaze was increased. Furthermore, if the tin and zirconium were added to the glaze batch as hydrates or basic compounds, the surface of the enamel was much improved. The author considered that such colouring substances occurred possibly as highly dispersed sols.

The following two batches were given :

	1.	2.		
Silica	35	35	parts by weight.	
Red lead	34	32	,,	,,
Kaolin	10	10	,,	,,
Soda ash (ignited)	14	12	,,	,,
Zinc oxide	1	1	,,	,,
Zirconia	5	3	,,	,,
Calcium carbonate	1	—	,,	,,
Tin dioxide	—	7	,,	,,
	100	100		

W. S.

13. The Interaction of Sodium Chloride and Silica. F. H. CLEWS and H. V. THOMPSON (*J. Chem. Soc.*, 1922, **121**, 1442).—The sodium chloride–silica mixture used in the experiments had the following composition : H_2O, 1·58; SiO_2, 50·06; NaCl, 47·85; Al_2O_3, 0·14; Fe_2O_3, 0·06; MgO, 0·06; total, 99·75 per cent. It was heated in platinum in an electric tube furnace, and a purified stream of air or nitrogen, moist or dry, passed over it.

In dry air, chlorine, sodium silicate, and a small quantity of hydrochloric acid (probably from traces of moisture) were produced whilst in moist air, hydrochloric acid, sodium silicate, and a little chlorine were obtained. In dry nitrogen, only traces of hydrochloric acid were produced, possibly due to small amounts of moisture inadvertently introduced, but in moist nitrogen the products of reaction were hydrochloric acid and sodium silicate. The reactions might be :

(a) $4x\text{NaCl} + y\text{SiO}_2 + x\text{O}_2 \rightarrow 2x\text{Na}_2\text{O},y\text{SiO}_2 + 2x\text{Cl}_2$.
(b) $2x\text{NaCl} + y\text{SiO}_2 + x\text{H}_2\text{O} \rightarrow x\text{Na}_2\text{O},y\text{SiO}_2 + 2x\text{HCl}$.
(c) $4\text{HCl} + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + 2\text{Cl}_2$.

Reaction (a) occurred in a current of dry air, (a), (b), and (c) in moist air, and (b) in moist nitrogen.

In moist air, reaction (b) predominated. Up to 1000°, the magnitude of the reaction was very small, and was just discernible at about 600°. The maximum reaction was observed when 3·5 gm. of the sodium chloride silica mixture were heated at 1000° for thirty-six hours in a stream of moist nitrogen; 53·7 c.c. of decinormal hydrochloric acid were formed, corresponding with a decomposition of 18·74 per cent. of the salt. The effect of the

temperature on reactions in dry air were illustrated by the following figures, obtained by heating 1 gm. of the sodium chloride–silica mixture (containing 1·58 per cent. of combined water), for six hours.

Rate of flow, 112 c.c. per hour.				Rate of flow, 88 c.c. per hour.			
Temp.	C.c. of N/100- HCl.	Temp.	C.c. of N/100- HCl.	Temp.	C.c. of N/100- HCl.	Temp.	C.c. of N/100- HCl.
1045°	41·7	784°	6·2	1045°	30·2	828°	9·1
1010	29·5	725	5·1	1000	16·5	753	8·3
930	25·1	675	3·7	947	16·4	640	8·0
880	15·6	575	3·3	900	14·3	569	6·7
827	10·2						

The acid produced at the lowest temperatures, 575° and 569°, without corresponding alkalinity in the residue, was probably derived from traces of acid retained during the preparation of the mixture. The lower temperature limit of the reaction could therefore be fixed between 640° and 575°, but at much higher temperatures it was still very feeble.

Comparative heatings for six hours of 1 gm. of the mixture in (a) dry air and (b) moist air gave the following results :

Rate of flow, 88 c.c. per hour through tubes 9—10 mm. diameter.					
	Dry air.	Moist air.		Dry air.	Moist air.
Temp.	C.c. of N/100- HCl.	C.c. of N/100- HCl.	Temp.	C.c. of N/100- HCl.	C.c. of N/100- HCl.
1045°	30·2	100·9	753°	8·3	12·3
1000	16·5	70·1	708	—	10·0
947	16·4	45·9	640	8·0	8·5
900	14·3	31·3	569	6·7	7·8
828	9·1	27·3			

The proportion of sodium chloride had only a subsidiary effect on the magnitude of the reaction, the important factor being the area of contact of the reacting substances.

Sodium chloride at 1000° converted *quartz* into *tridymite*, probably owing to solution and recrystallisation. Ground *quartz* was heated at 1000 ± 20° in a platinum crucible and the density determined after each period of heating. The results on heating with and without sodium chloride were given as follows :

Period of heating (hours).	Density.	
	Without NaCl.	With NaCl.
0	2·634 (9·2°)	2·634 (9·2°)
25¼	2·623 (14·4°)	2·317 (15·5°)
48¾	2·627 (9·8°)	—
51¼	—	2·285 (14·1°)
79½	—	2·284 (15·5°)
129¼	2·623 (13·7°)	—

Of the different varieties of silica tested, namely, *quartz*, precipitated silica, and *tridymite*, *quartz* was the most reactive to sodium chloride

at 1000°.   Dry 50 per cent. mixtures of (a) *quartz,* (b) precipitated silica, and (c) *tridymite* were made with sodium chloride.   One gram of the respective mixtures was heated for six hours in moist air at 1003°, the rate of flow being 88 c.c. per hour through tubes 9–10 mm. in diameter.   *Quartz* gave 50·5, precipitated silica 42·0, and *tridymite* 38·8 c.c. of centinormal hydrochloric acid.   F. W. H.

14. The Moulding of Quartz Goods.   W. Schuen (*Ker. Rundschau,* 1923, **31**, 22).—Short, thick-walled cylinders were first made by fusing washed pure sand in an electric furnace.   The electrodes and carbon resister were then removed and the furnace turned to the horizontal position.   For the manufacture of quartz tubing a blowing head was connected to one end of the viscous cylinder and the other end of the cylinder gripped with tongs and rapidly drawn out, a circular cross section being maintained by air through the blowing head.   The process yielded tubes down to 15 mm. and even 10 mm. diameter.   For still thinner tubing, the larger ones were reheated and a second drawing was made. The twice drawn tubing had both an inner and outer glazed surface, whilst the tubing only once drawn had a glazed inner surface, the outer surface being covered with unmelted sand.   The time available for working was less than that with ordinary glass.   It was still difficult to produce long quartz tubes of uniform bore.

For the manufacture of basins, crucibles, and muffles, pasty quartz cylinders were blown by compressed air in iron plate moulds.

Hot quartz bodies offered a high initial resistance to blowing and the initial pressure must be uniformly distributed and after blowing had once commenced the supply of compressed air must be diminished or some of it allowed to escape.

Usually twelve to fifteen objects were obtained from one quartz cylinder.   These were separated by thin carborundum or emery discs.   Any small irregularities were removed by grinding and the rough surface was sand blasted.   Some objects were now worked in a powerful hydrogen–oxygen flame.

Pressing was seldom carried out, as the cooling caused by the plunger and the mould prevented the pressing of somewhat complicated shapes.

Volatile substances were sometimes used for blowing.   After one end of the cylinder had been pinched together, a small piece of moist filter-paper was inserted and the other end quickly closed. When dexterity was used this method had the advantage of not needing the connection of a blowing head.   The charge or " pill " had to be measured so that a correct gas pressure was developed. A disadvantage was that a stain was sometimes left where the volatile substance touched the quartz.   The stain was small when pure moist filter-paper was used, but objectionable if such substances as ammonium chloride were used.   H. W. H.

15. Determination of Sulphate, Chloride, and Carbonate in Soda–Lime Glass.   M. Ikawa (*J. Chem. Soc. Japan,* 1921, **42**, 768; *from Chem. Abs.*).—Analyses of various window glasses

showed that SO_4 (as Na_2SO_4) varied from 0·667 to 1·045 per cent.; non-sulphate S (as Na_2SO_4) from 0·0 to 0·108 per cent.; Cl (as NaCl) from 0·066 to 0·154 per cent.; and CO_3 (as Na_2CO_3) from 0·021 to 0·055 per cent.   F. W. H.

16. Apparatus for Measuring the Thermal Conductivity of very Thin Specimens of Poor Conductors. M. S. VAN DUSEN (*J. Optical Soc. Amer.*, 1922, **6**, 239).—The method consisted essentially in comparing the temperature gradients in two metals placed in series and separated by the poor conductor concerned.
                                                        J. R. C.

17. The Passage of Hydrogen through Quartz Glass. J. B. JOHNSON and R. C. BURT (*J. Optical Soc. Amer.*, 1922, **6**, 734).—The rate of flow of gases through fused silica made from quartz crystals was measured over the range 300° to 900°. A bulb of this material was kept in an atmosphere of the gas and the increase of pressure due to the infusion of the gas observed, the initial pressure being about 10^{-4} mm. Preliminary tests on fused silica made from quartz sand showed that this material was unsuitable for high vacuum apparatus even at room temperatures. With the quartz crystal glass a perceptible diffusion of hydrogen was found to start at 300°, of nitrogen at 600°, and in each case it increased rapidly with the temperature. It was suggested that the passage of the gas might accompany a modification in the structure of the non-crystalline material. It was shown that a well evacuated bulb of 1000 c.c. capacity could be kept in air at 400° for one hundred hours before the pressure reached 10^{-4} mm.
                                                        J. R. C.

18. The History of Optical Glass. W. ZSCHOKKE (*Zeitsch. Instrumentenkunde*, 1922, **42**, 208).—P. L. Guinand, of Les Breults, Neuenberg, was the first to produce homogeneous crown and flint glass. He was born in 1748, the son of a joiner, and he learnt this trade. Apparently he specialised in making small clock cases, and as he was short-sighted, needed good spectacles. He could not obtain a satisfactory pair, owing to the poor quality of the glass, so he decided to make good glass himself. He succeeded in 1790 in producing glass entirely free from cords and streaks. His subsequent history and travels are recorded by the author in detail. He died in 1824, and his business was carried on by his widow with the help of T. Daguet. The factory built by these two in Solothurn still stands. Daguet lived from 1795 to 1870, and the author in 1921 spoke to two people who knew him well, and from whom he obtained some interesting particulars.   J. R. C.

19. Method for the Manufacture of Hollow Glass Bodies, particularly for Electric Glow Lamp Bulbs. E. BRANK, Berlin, Assignor to PATENT-TREUHAND-GESELLSCHAFT FÜR ELEKTRISCHE GLUHLAMPEN, Berlin (U.S.A. Pat., June 27th, 1922, No. 1420996. Filed September 3rd, 1921, No. 498484).—In making small electric lamp bulbs with opal reflecting backs, enamel was applied by a

brush or otherwise to a clear glass from which the bulb was to be blown. The enamel thus put on was permitted to dry, preferably by heating the tube to between 100° and 300°. When thoroughly dry, the glass tube was further heated and blown up to the desired shape, the temperature required to do this being sufficient to cause an intimate connection between the enamel and the glass. The enamel, in fusing completely and welding with the clear glass, formed an excellent reflecting opaque surface. From a glass tube of suitable length a number of bulbs might be blown, by painting on the enamel paste at short predetermined distances along the tube.

S. E.

20. Irregularities in the Expansion of Glass. P. LAFON (*Compt. rend.*, 1922, **175**, 955; compare this Journal, 1920, **4**, ABS. No. 274; 1922, **6**, ABS. No. 114).—Chevenard's differential method of measuring the expansion was employed, and the relation between dilatation and temperature was shown graphically, as in the curves, Figs. 2, 3, 4, and 5, given below.
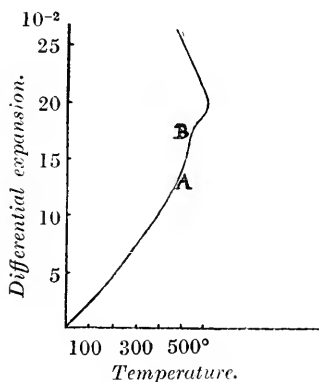
FIG. 2.
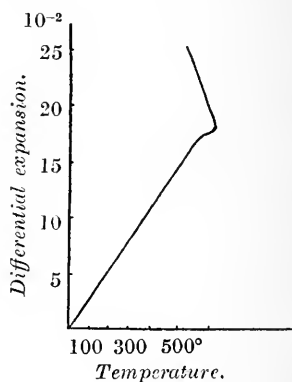
FIG. 3.
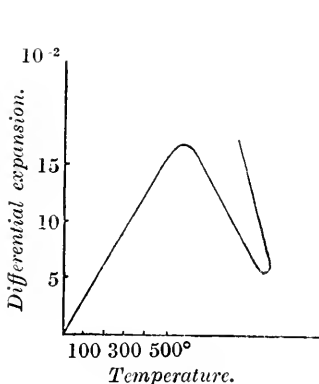
FIG. 4.
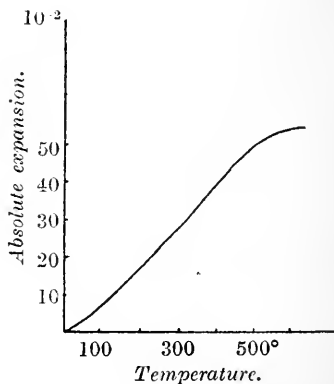
FIG. 5.

Curve, Fig. 2, was obtained, using a common glass (*a*); curve, Fig. 3, from the same glass, after thorough reheating. Fig. 4 was obtained using a crown optical glass (*b*) and Fig. 5 showed the relation between absolute expansion and temperature. In Figs. 2 and 4, the first and rectilinear part was followed by a short curve, indicating less expansion, particularly noticeable in curve Fig. 2, part AB. This anomaly was not evident in curve Fig. 3; hence reheating eliminated the decreased expansion, which arose from destruction of internal strains. The rapid drop in the curves extended over an interval of temperature dependent on the composition of the glass, being considerable for glass (*b*), in curve Fig. 4. The fourth, and almost vertical part of the curves commenced at the temperature at which incipient softening of the sample took place. The third and fourth parts of the curves were reversible.

Lebedeff, who had also observed the phenomenon, attributed it to the reversible transformation of quartz, but the author obtained the change in expansion at a temperature as low as 400°, and, moreover, the silica in glass was amorphous.

The compositions of the glasses corresponding with the curves, and their percentage changes in length at temperatures T, were as follows :

	T.	Per cent. change.
A. Glass (*a*)	600°	0·04
B. Glass (*b*)	550	0·40
C. Flint Glass	400	0·10

	SiO_2.	K_2O.	Na_2O.	CaO.	FeO.	Al_2O_3.	B_2O_3.	As_2O_3.	PbO.
A	67	—	10·0	16·0	3·0	4·0	—	—	—
B	72	4·69	10·33	1·21	—	1·41	10·0	0·36	—
C	25·81	3·17	1·37	—	—	—	—	0·13	69·52

V. D.

21. Process for Making Bifocal Lenses. H. FENNEL, Everett, Mass., U.S.A. (U.S.A. Pat., January 9th, 1923, No. **1441566**. Filed November 9th, 1922, No. **599864**).—This in-
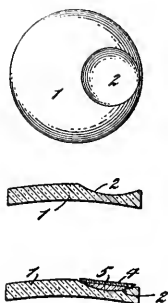
FIG. 6.

vention relates to the manufacture of bifocal lenses in which the reading segment is entirely enclosed within the body of the main lens. A spherical depression, 2 (Fig. 6) is formed in a block of

crown glass, 1, and a composite button consisting of a lens of flint glass, 5, and a plate of crown glass, 4, is fused into it. The underside of the flint glass, 5, has a convex curvature preferably slightly stronger than that of the recess, 2, to assist the fusing-in process. After fusing in, the bifocal blank is ground and polished to any desired curvature, care being taken always to leave a complete layer of crown glass over the flint glass lens, 5, in order to protect it from scratching and weathering action.   S. E.

22. **Elasticity and Symmetry of Quartz at High Temperatures.** A. PERRIER and B. DE MANDROT (*Compt. rend.*, 1922, **175**, 622).—The specimens, in the form of plates, were supported on two knife-edges, bent by a known weight acting at the centre, and the amount of bending measured by means of reflection from plane mirrors attached to the ends of the plates. The temperature ranged from 18° to 1200° approximately, and Young's modulus was measured parallel to, and normal to, the optical axis, and also in oblique directions, $\pm 50°$. The results obtained were as given below :

$t.$	$E_1.$	$t.$	$E_2.$	$t.$	$E_{+50°}.$	$t.$	$E_{-50°}.$
18°	10,480	18°	8,010				
74	10,370	140	7,980	15°	7,850	15°	13,060
105	10,300	210	7,940	293	7,450	498	9,900
160	10,200	326	7,825	496	6,670	548	8,120
232	10,010	404	7,710	548	6,110	582	9,280
340	9,730	457	7,520	581	9,060	648	10,060
436	9,350	498	7,250	648	10,090	694	10,260
544	8,400	542	6,520	694	10,280		
567	7,440	561	5,630				
572	6,960	564	5,470				
574	6,510	568	4,860				
574·5	6,320	573	3,570				
575	6,020	574	3,210				
576	6,680	576	9,030				
577·5	9,060	585	10,530				
584	9,560	599	10,910				
596	9,710	642	11,340				
654	9,800	733	11,660				
731	9,860	796	11,820				
828	9,900	948	12,020				
992	9,920	1,140	12,190				
1,078	9,910						

t=temperature, E_1=Young's modulus parallel to the axis, E_2=Young's modulus perpendicular to the axis, the values being expressed in kg./cm.^{2}, $E_{+50°}$ and E_{-50} =Young's modulus in the oblique directions.

Up to the transition point, α to β quartz, the modulus decreased, slowly at first, then more rapidly, as the point of transition was approached. Beyond this point (575°), the values increased considerably for a small rise in temperature, over a certain range, then this increase became less, until, in the region of 1100°, it was almost negligible. The values obtained differed along the axis, and perpendicular to it, and the difference between the moduli for the two oblique directions disappeared at the transition point. This indicated clearly that at this point the crystal of quartz passed from the rhombohedral to the hexagonal system.   V. D.

23. Summary of the Literature Relative to the Formation of Film on Polished Glass Surfaces. G. W. MOREY (*J. Opt. Soc. Amer.*, 1922, **6**, 688).—The paper dealt with the formation, appearance, cause, and prevention of "film" on polished glass surfaces. Although filming was met with in enclosed optical instruments, especially on reticules, yet when the instruments were assembled with care, as was the case with periscopes, the defect was not observed. The surface of the glass did not show sign of corrosion on removal of the globular deposit, for the formation of which moisture and dirt or grease were necessary. Japan black and blacks containing pitch or bitumen caused "film," as also did machined and uncleaned aluminium, and animal matter or beeswax.

In order to avoid "film," the glass chosen for use in instruments should be of good quality, determined by test, and the utmost care taken to clean the glass surfaces, and to ensure that no moisture or grease, or material likely to yield these, was present in the space in which the glasses were enclosed.   V. D.

24. Contamination of Water Samples with Material Dissolved from Glass Containers. W. D. COLLINS and H. B. RIFFENBURG (*J. Ind. Eng. Chem.*, 1923, **15**, 48).—Distilled water, tap water, and a solution of sodium carbonate (0·5 gm. per litre) were stored in good and in poor bottles for periods from seven to fifteen months, and the carbonate, bicarbonate, and hydroxide radicles were determined by titration. Filtered samples of the solutions were also evaporated to dryness, and weighed after heating for one hour at 180°.

It was found that water did not dissolve enough glass in a month from good bottles to cause any appreciable difference in the usual mineral analysis. No serious change took place in six months.

On the other hand, water stored in poor bottles for a few hours, or a week, dissolved so much glass as to affect the analysis appreciably. The following table states the results obtained from an examination of water stored in poor bottles :

Analyses Showing Solution of Material from Poor Glass Bottles.
(Parts per Million.)

	Tap water.			Distilled Water.
		One year in bottle.		Fifteen months in
	As drawn.	No. 1.	No. 2.	bottle.
Silica	8·2	39·0	53·0	142·0
Fe	0·15	0·15	0·15	trace
Ca	18·0	19·0	18·0	1·1
Mg	4·3	3·3	3·2	0·2
Na and K	2·2	18·0	24·0	22·0
(OH)	0	0	0	2·0
CO_3	0	24·0	31·0	34·0
HCO_3	52·0	41·0	41·0	0
SO_4	19·0	21·0	22·0	3·5
Cl	4·0	4·0	4·0	trace
NO_3	3·9	3·9	3·8	trace
Total dissolved solids	91·0	150·0	177·0	208·0

The greatest changes in the character of the solution were the considerable increases in silica and sodium and the change in the alkalinity from bicarbonate to carbonate and hydroxide.

Examination of the solution stored in a glass container for a month, including determination of the total solids, silica and alkalinity was suggested as a means of testing the resistance of the glass to attack.   V. D.

25. Measurements of the Fizeau Effect in Quartz. P. ZEEMAN and A. SNETHLAGE (*Proc. K. Akad. Weten. Amst.*, 1920, 22, 513).—The apparatus had been previously described (1920, 22, 462).   Quartz rods were used with end planes normal to the optical axis, and dimensions $10 \times 1.5 \times 1.5$ cm.; in one case, the column consisted of 10 such pieces and was 100 cm. long, in another case 14 pieces were used, and its length was 140 cm.   A 12 amp. arc lamp was used, and the light filtered to render it sufficiently monochromatic.   The central band was observed and noted by subjecting the interference bands to some modification as an indication before the experiment.

The velocities taken varied between 750 and 950 cm./sec., the length of the quartz column being 100 cm. in nine series of photographs and 140 cm. in two series of photographs.

	Displacement Δ.	
Wave-length of light λ.	Observed.	Calcd.*
4750 (violet)...............	0.156 ± 0.007	0.166
	0.156 ± 0.008	
5380 (green)	0.148 ± 0.006	0.143
	0.148 ± 0.012	
6510 (red)	0.125 ± 0.007	0.115
	0.123 ± 0.014	

A formula was deduced, and corroborated strictly from the theory of relativity, in one direction,

$$\Delta = \frac{4lw}{c\lambda}\left(\mu - 1 - \lambda\frac{d\mu}{d\lambda}\right)$$

in the other direction, $\Delta = \dfrac{2lw}{c\lambda}\left(\mu - 1 - \lambda\dfrac{d\mu}{d\lambda}\right).$

                                                    W. C. S.

26. Adsorption of Odorous Molecules in the Surface of Solids. H. ZWAARDEMAKER. (*Proc. K. Akad Weten. Amst.* 1920–21, 23, 654).—Three possible causes were : 1. The presence of a condensation layer of air and water vapour which was on nearly all surfaces.   2. The direct adsorption if this layer had been removed. 3. Electrically charged surfaces.

Pyridin was scarcely adsorbed in glass, even when a large quantity was present in the air; valerianic acid, however, was retained for a very long time when only present in the transmitted air in small quantity.   Apparently in some cases the condensation layer was

* From Kohlrausch's formula.

saturated and finally imparted a portion of the dissolved substance to the sub-layer, so that odorous matter could be retained almost for ever, adsorption continuing even after removal of the condensation layer, as was shown by glass after a short exposure to musk.

<div align="right">W. C. S.</div>

III.—Lamp-worked and General Scientific Apparatus.

27. A Modified Orsat Apparatus for Gas Analysis.   O. I. HANSEN (*Chim. et Ind.*, 1922, **7**, 494).—The author stated that most of the errors in analyses obtained by the use of the Orsat apparatus were due to temperature variations, which were occasioned
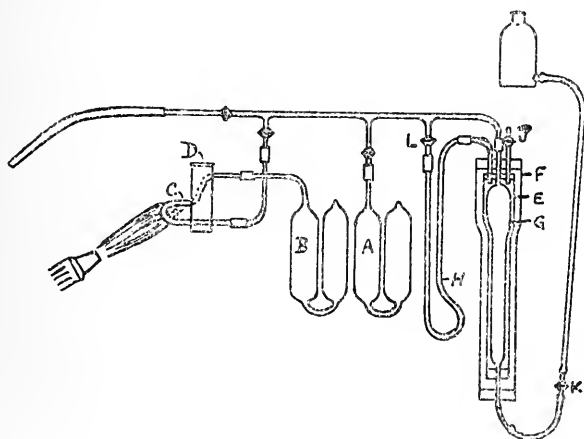
Fig. 7.

by faulty design.   He therefore enclosed the graduated burette, G, in an air-jacket, E, which contained a little distilled water.   The whole was then enclosed in a water-jacket, F.   The air-jacket was connected to a manometer tube, H, and the stop-cock, J, could be utilised to equalise the pressure in the air-jacket, so avoiding too great a correction for temperature and pressure.   F. W. H.

28. An Apparatus for Small Scale Flotation Tests.   H. L. SULMAN and H. F. K. PICARD (*Chem. Trade J.*, 1923, **72**, 130).— Preliminary tests having shown the best reagents and the most suitable concentrations to employ, the majority of the metal was separated from the mineral ore, etc., by shaking with reagent chosen in a bottle similar to F, and separating off the sand, etc., from the froth.   This did not give a complete separation, however, and the residue was transferred to the " sub-aëration " apparatus shown, by pouring in through A, after E had been partly filled with

the circuit liquor by opening J and applying gentle suction at I. The air current was provided by the rubber bulb, B, worked by hand and driving a stream of small bubbles through the septum, C. A froth an inch in height was maintained in D, and as often as was desirable, by blowing slightly harder, portions are blown through into the collecting vessel, F, where the froth breaks down, permitting the deposited material to be removed through G. This was continued until the froth was found to contain no more material and
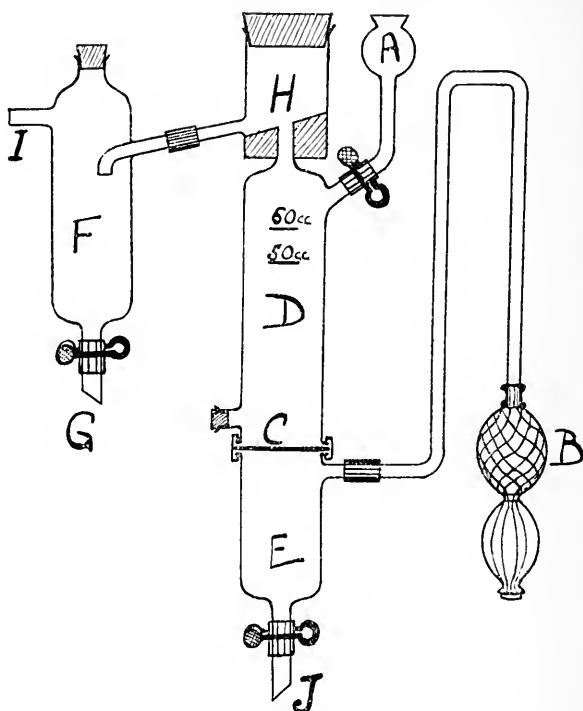
Fig. 8.

the sub-aëration concentrate was added to that obtained from the rough shaking bottle. The emulsion for the circuit liquor was prepared in a 200-c.c. vessel with fixed vanes between which other vanes were rotated at 5000 r.p.m., the clearance between fixed and moving vanes being $\frac{1}{6}$ inch. The ore sample should be crushed at least to 60 I.M.M. screen—preferably to 80—and in small-scale work distilled or rain-water should be used. In the apparatus described, a 10 or 12 gm. sample—yielding about 50 gm. of ore pulp—gave results as accurate quantitatively as a large-scale experimental unit.

The oil necessary for these quantities of ore and water was so small that it was best added as a dilute aqueous emulsion, or if an acid, in the form of a weak solution of its sodium soap.   M. P.

29. Sealing Platinum through Pyrex Glass. G. E. GIBSON and W. A. NOYES, Jnr. (*J. Amer. Chem. Soc.*, 1923, **44**, 2099).—Since a vacuum-tight seal of platinum through pyrex glass could not be made, two seals were made at *A* and *B*, the space in between being maintained through *C* at a very low pressure (0·0001 mm.). This enabled the pressure in the main tube, *D*, to be maintained constant for long periods of time. M. P.
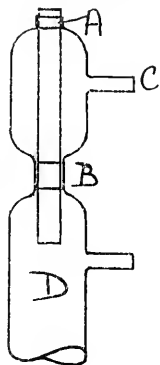
FIG. 9.

30. A Dispensing Bottle for Concentrated Alkali Solution. W. J. GELDARD (*J. Ind. Eng. Chem.*, 1923, **15**, 153).—An apparatus suitable for delivering concentrated alkali solution was constructed as shown. The syphon pipette, *D*, was 32 mm. in diameter and 150 mm. long, having a capacity of 90—100 c.c. Air pressure applied at *A*, with the finger on *B*, caused the solution to rise in *C* and fill *D*, and when sufficient " head " developed in *E*, to overflow through *F*. At this point the finger was removed from *B* and the contents of the pipette, *D*, siphoned over through *F*, which was constructed at such an angle that the solution ran down the neck of a Kjeldahl flask without mixing unduly with the acid solution contained in the latter.

M. P.
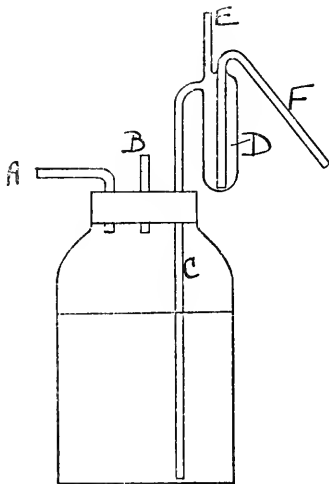
FIG. 10.

31. Specifications for Bourdon Tube Pressure Gauges. F. J. SCHLINK (*J. Optical Soc. Amer.*, 1922, **6**, 899).—These specifications were advanced by the American Engineering Standards Committee. The gauges were divided into two groups; those for stationary use as air, steam, or water pressures, and those for use as reference standards for test purposes. The original paper should be consulted for details.

J. R. C.

32. Differential Thermometer and its Application. A. W. C. MENZIES and S. L. WRIGHT (*Proc. National Acad. Sci. U.S.A.*, 1921, **7**, 77; *Zeitsch. Instrumentenkunde*, 1922, **11**, 344).— The thermometer consisted of a glass tube about 12 cm. long and 1 cm. thick, with a mm. scale, and ending in a bulb at each end. After removing all the air, it was filled about one-third full with water. The bulbs and the remainder of the tube contained water-

vapour, the tension of which differed if both bulbs were not at the same temperature. When the instrument was used in a vertical position, the difference in tension was measured by the height of the column of water. If the temperature was given approximately, the temperature difference between the two bulbs could be ascertained, knowing the density of water and the temperature coefficient of its saturation pressure, merely from the length of the column of water. At $t=57°$, or $80°$, or $100°$, a column of water 1 mm. high corresponded with a difference in temperature of $0\cdot01180°$, or $0\cdot004969°$, or $0\cdot002599°$, respectively.

The differential thermometer possessed an undoubted advantage over the Beckmann thermometer, for the determination of boiling points and estimations were independent of alterations of the boiling points due to variations in atmospheric pressure.

In use, the thermometer was not immersed in the liquid, which was raised by a small automatic pump and constantly dropped on the bulb of the thermometer. The pump consisted of a bent glass tube widened at its lower end and immersed in the liquid. A blast of vapour entered the tube, a part of the liquid rose in the tube and was driven out at the other end. Fig. 12 shows the complete boiling apparatus with a reflux condenser.   E. M. F.
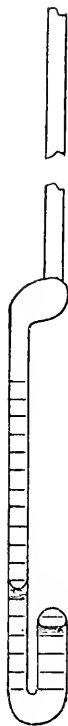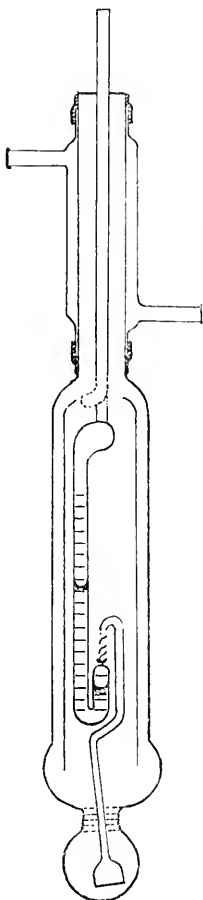
Fig. 11.   Fig. 12.

IV.—Decorated Glass.

33. Glass Painting and Etching; Part II, Etching.   L. SPRINGER (*Glashütte*, 1922, **52**, 803, 819; 1923, **53**, 3, 19, 35, 51, 67).*—A review of the methods employed for the process of etching. It was suggested that the best way of determining the strength of aqueous hydrofluoric acid was either by neutralising with soda or

* For abstract of Part I, see this JOURNAL, 1922, **6**, 287.

potash and finding the weight of the alkali needed for a known
weight of the acid; or by finding the specific gravity of the acid in a
gutta-percha bottle of known weight and volume. In the latter case
the author found the specific gravity of freshly distilled acid to be
1·33, that of a 60 per cent. acid containing 0·5 per cent. sulphuric
acid 1·27, and that of a 35 per cent. acid containing 0·5 per cent.
sulphuric acid and 18 per cent. fluorsilicic acid 1·35.

It was found that concentrated or only slightly diluted hydro-
fluoric acid treated for five to fifteen minutes gave a rough, bright-
matt etch; when the acid was diluted with 5 to 12 parts of water
and exposed for thirty to sixty minutes a deep clear etch was
obtained. In the latter case, the result was deeper the stronger
the acid, but the brightness increased with decrease of acid concen-
tration.

Solutions of the neutral salts of strengths 100 gm. NaF and
200 gm. NH_4F per litre were used, and the glass was exposed for
ten to thirty minutes. The sodium salt had no effect, whilst the
ammonium salt gave only a faint matt result. When, however, a
little strong acid (such as sulphuric, hydrochloric, or hydrofluoric)
was added, it was then found that strong concentrations of the
salts gave a matt etch, whilst dilute solutions produced a deep,
bright result. Acid fluorides etched in a similar way, but without
the addition of free acid. A. C.

**34. The Arrangement of a Machine Shop for Grinding
and Polishing Glass.** WILHELM HANNICH (*Ker. Rundschau*, 1922,
30, 277 and 298).—For paste beads, Rossler's machine was suitable
and consisted of a shaft and a vertically moving stone. The latter
had grooves radiating from the centre and was enclosed in a perfor-
ated zinc plate case. Into this case the beads were poured and
then covered with water. Zinc plates guided the beads against
the stone and the beads moved forward in a circular path. When
finished they collected in the bottom of the case.

For artificial gems the small blanks were accurately cemented in
uniform lines on a plate. The latter was fastened on an arm and
the stones were held up against a grindstone. By turning the
arm at least two angles could be ground on each stone. Tin discs
and rouge were generally used for polishing.

Weisskopf's machine was similar but worked on glass rods.
The stone had several grooves and the rods were ground into faces
along their entire length and uniformly divided. The glass stems
were held up against the stone by rubber. After grinding, the
portions were separated and fire polished. Only enamel beads
were uniformly ground.

To deal with buttons and small lamp lenses, a main shaft mounted
horizontally held four grinding stones situated 15 to 20 cm. apart.
The stones contained several deep grooves allowing various sizes
to be worked. The working place was on that part of the stone
moving outwards. The ware was held in hollow moulds mounted
on spindles. The latter had cogwheels keyed on at their lower
end. The ware was held up against the stones by spring pressure

on levers and each piece revolved during the grinding. Irregularity sometimes resulted from uneven grinding due to the uneven hardness of the blanks or owing to the two halves of the moulds not registering accurately. This necessitated longer grinding to obtain a symmetrical result. The machine worked best on ware having a diameter up to 7 mm.

Bourne's machine consisted of a ring fixed to a disc which could be revolved at various speeds by a step drive. The glass was cemented on a disc which revolved rapidly. The latter was fixed on a carriage which could be adjusted vertically to facilitate changing. The size and shape of the lens were determined by the diameter of the ring. In a modification the lens was held in hewn stone on a carriage and was moved up against another hollow stone driven by gearing.

A machine suitable for grinding serviette rings consisted essentially of an iron disc of from 1·0 to 1·2 m. diameter having a belt drive underneath. Above, and almost making contact with the disc, were several small discs mounted in free bearings. The number of small discs depended on the size of the grindstone, but was usually 2 to 4. A workman served one or two such discs. A working place was arranged on the two accessible sides. Each disc had six to eight rounded or angular compartments. The glass objects were placed loosely in the compartments and pressure was applied to the discs by suitable iron pistons having rubber faces at the bottom. The small discs were easily set into operation by a hand lever and moved round the stone in a circular path. A rapid rate of working could be obtained. The machine was used with an iron disc and sand for rough grinding, a stone disc for smoothing, and a wooden disc for polishing.

In another arrangement several glass objects were gripped in an iron ring which could be tightened by a screw. Hollows and vacant spaces were filled with wooden blocks. These rings could be either fixed or held loosely in the bearings. The grindstone was uniformly worn.

A machine for polishing serviette rings gave a much greater production than that attained by hand methods. In this machine a brush-covered drum was revolved by a belt-driven shaft in a suitable case. Wooden rollers having iron shafts were mounted in six to eight hollow axles supported in the raised sides of the case. The axles were revolved in the opposite direction to the drum by a chain drive off the main shaft. The wooden rollers had screw clamps on one side to receive the rings, and were made specially for each size of ring. Each roller generally held three dozen rings. The drum revolved at 300 revolutions per minute and the rollers at 15 to 20. The number of rollers could be varied during the working. The rings must not be loosely mounted and if only a few were to be worked the rollers were filled with rough ware.

Balls, plum grooves, olives on tumblers could be cut by Kutzscher's machine, the glass, in a holder, being pressed by weights upon a grindstone. The stone was shaped according to the pattern required.

In glass grinding, special attention must be directed to speeds of revolution, and machines should not be used for work for which they were not designed. A speed too slow wasted time. A speed too fast flung off the grinding material such as sand and water and the glass and stones became hot. As a result the stone crumbled and the glass even melted, the ground surface exhibiting "heat-cracks." The normal speeds were : iron discs, 450—480 revolutions per minute; stone discs, 500—550; wooden discs, 600 and upwards.

In estimations, the power consumption could be taken as $\frac{1}{2}$ h.p. per working tool. The necessary power for each disc was about $\frac{1}{4}$ h.p.

For deep cutting a speed up to 900 could be used. For polishing, the speed might reach 1400. Amongst other things the speeds depended on the diameter of the discs.   H. W. H.

V.—Optics and Optical Instruments.

35. The Aplanatic Points of the Sphere. A. WHITWELL (*Optician*, 1923, **64**, 326).—Young's construction, for finding the refracted ray corresponding with any ray incident on a refracting sphere, was given and the position and properties of the aplanatic points were described with its aid.   J. R. C.

36. A Geometrical Construction for Finding the Astigmatism of Oblique Pencils. A. WHITWELL (*Optician*, 1923, **64**, 369).—By means of the construction given (for which reference should be made to the original paper), the author claimed that, if the scale were fairly large, say 1 inch to the diopter, an accuracy could be obtained comparable to that yielded by the ordinary second approximate formula and four-figure logarithms. Three special cases were treated, namely, when the lens was plano-convex, double-convex, and meniscus-shaped.   J. R. C.

37. The Absorptive Power of the Eye for Ultra-violet Radiation. W. P. GRAHAM (*J. Optical Soc. Amer.*, 1922, **6**, 605).—It was found that the combined tissues of the eye absorbed the ultra-violet radiations of wave-length less than $0 \cdot 3134 \, \mu$. The lens had the largest region of absorption, and any injury or disease tending to increase the salt content in the eye radically changed the absorption. It was considered probable that the absorption in the eyes of cows, pigs, and sheep did not differ greatly from that of human eyes.   J. R. C.

38. A Mirror Aplanatic Telescope Corrected for Astigmatism and Curvature of the Field. H. VIOLETTE (*Revue d'Optique*, 1922, **1**, 397).—A mathematical treatment of the errors obtaining in a two-mirror telescope. It was shown that they can be eliminated by a system of lenses.   J. R. C.

39. A New Design of Brace's Half Shade Compensator.
G. SZIVESSY (*Zeitsch. Instrumentenkunde*, 1922, **42**, 183) (abstracted
from *Zeitsch. Physik*, 1921, **6**, 311).—The Babinet compensator
having been fitted with a half-shade device, one became necessary
for Brace's instrument. A mica splitting, 0·0002 mm. thick, and
accurately parallel was required. On account of the difficulty of
obtaining this, the necessary double refraction was produced by a
thin sheet of glass, subjected to a small pressure. Usually a micro-
scope cover-glass 0·1 mm. thick was employed. It was held between
two metal grips the distance apart of which could be changed and
thus a compression or tension applied.   J. R. C.

**40. The Measurement and Specification of Optical Char-
acteristics in Projector Performance.** G. W. MOFFITT (*J.
Optical Soc. Amer.*, 1922, **6**, 940).—The characteristics of cine-
matograph projectors were discussed. It was considered that an
optical bench test was too rigorous, and the testing of the pro-
jectors *in situ* was recommended. This would take account of
the fact that under working conditions the aperture of the projector
was not uniformly illuminated. Standard tests for definition,
screen illumination, and quality were suggested, quality being
defined as the ability to render faithfully the contrasts of the film.
Under that head came the defects known as " flare-spot " and
" flare," due to internal reflections in the lens.   J. R. C.

41. Methods of Calculating Lighthouse Lenses. A.
BLONDEL (*Revue d'Optique*, 1922, **1**, 161).—These echelon lenses
were originated by Fresnel and studied by Descartes and others.
Their construction was simple, because, on account of reducing
the cost, they were not achromatic. The author first gave a
graphical method of designing them and then a theoretical, log-
arithmic method. An example was designed in detail by both
methods.   J. R. C.

42. Theory of Toric Spectacle Lenses. A. GLEICHEN
(*Optician*, 1923, **64**, 350, 363, 393).—A continuation of the discussion
commenced in the paper referred to in this Journal (ABS. No. 356,
1922). Various special rays and beams were considered. As the
treatment was mathematical throughout reference should be made
to the original papers.   J. R. C.

43. Unit Surfaces of Cooke and Tessar Lenses. ALICE
EVERETT (*Proc. Phys. Soc.*, 1923, **35**, [ii], 55).—The author applied
the method of T. Smith (*Proc. Phys. Soc.*, 1913, **25**, 239; 1915,
27, 502; 1918, **30**, 221; 1921, **33**, 174) to tracing a number of
rays in an axial plane through the lens systems and to finding the
positions of the conjugate points on each ray. The loci of the
unit points were shown to be surfaces only when the chief rays
were bound by some condition such as passing through a fixed
point. Within the region for which the lenses were designed, the
curvatures of both object and image unit point loci were convex
to the light source, that of the image locus being greater than that

of the object locus. The data obtained did not coincide with the theoretical conclusions drawn by Smith either for a thin system or for an ideal thick system, but were more in accord with those for the latter. M. P.

44. Galilean Telescope with an Enlarged Field. *Revue d'Optique*, 1922, **1**, 198).—The objective was a doublet of which the concave lens had one face plane. The eyepiece consisted of two lenses separated by a distance at least equal to the focal length of the negative lens. With such an arrangement, the eyepiece could be corrected for spherical and chromatic aberrations without distortion, the field thus being enlarged. A special mechanical device was used in order that a large objective could be employed without the instrument being unduly cumbersome. J. R. C.

45. Schwarzschild's Sextant. H. CHRÉTIEN (*Revue d'Optique*, 1922, **1**, 232).—The instrument was exceptional in that a new artificial horizon was employed. J. R. C.

46. An Erecting Monocular Microscope. (*Revue d'Optique*, 1922, **1**, 250).—The optical system consisted of an achromatic objective the focal length of which was 48 mm., an erecting prism system, and a Huyghen's eyepiece. J. R. C.

47. Photometric Glasses. M. TSCHERNING (*Revue d'Optique*, 1922, **1**, 252).—A series of filters was constructed transmitting percentages of the incident light which varied logarithmically. For example, the first transmitted one-tenth, the second one-hundredth, and so on. For larger transmissions, smoked glass could not be used, owing to the small thicknesses required. Instead, a gelatine film coloured with an aniline dye was cemented between two glass plates by means of Canada balsam. J. R. C.

48. A New Refractometer. H. SCHULZ (*Zeitsch. Instrumentenkunde*, 1922, **42**, 218).—The instrument was designed for the examination of sugar solutions. As with the Zeiss sugar-refractometer, the principle was that of the Abbe instrument. In the Zeiss instrument, the telescope could rotate about a horizontal axis, but it was stated that appreciable systematic errors arose in the measurement of this rotation. In the new refractometer, made by Goerz, the double prism and scale were made to rotate by means of a toothed wheel. The errors were obviated and the instrument was more serviceable. J. R. C.

49. On a Solenoscope. S. NAKAMURA (*Jap. J. Phys.*, 1922, **1**, 21).—The solenoscope was an optical instrument designed to examine the physical condition of the inside wall of a gun-barrel. It consisted essentially of a long, narrow tube about 70 cm. long and 6 mm. diameter, fitted with optical arrangements. A microscope objective of a few millimetres focal length was fixed at the remote end of the tube and formed an image of the barrel wall just behind the objective. By means of a number of lenses, the last image was brought to the near end of the tube to be observed

by a suitable magnifying eyepiece. Difficulty was encountered in devising a suitable optical arrangement to bring the image formed by the micro-objective to the near end of the tube and, at the same time, secure the greatest possible brightness. The device adopted was that commonly used in certain periscopes of combining a telescope and a collimator. The arrangement was fully described as was also a similar instrument for photographic purposes.   F. W. H.

50. The Dioptrometer : An Apparatus for Measuring the Power of Commercial Lenses. H. F. KURTZ (*J. Optical Soc. Amer.*, 1923, **7**, 103).—The development of the final apparatus was traced through a number of preliminary arrangements, to each of which there was some objection. The optical system of the dioptrometer in its final form consisted of a telescope, focussed for parallel light which was incident on it from the lens to be measured. A standard lens was employed to put a virtual image of an object in the focus of the test lens, in order to provide the parallel beam. The power of the test lens was read directly from a scale, according to the position of the standard lens.   J. R. C.

51. The Mechanics of Optical Polishing. E. THOMSON (*J. Optical Soc. Amer.*, 1922, **6**, 843).—The author controverted the plastic flow theory and, indeed, regarded glass as a truly solid substance, being of opinion that the process of polishing was the same as in the case of crystalline materials. It was considered that the particles of rouge embedded themselves in the pitch and produced a clean cut in the glass, distinct from the scratch produced by abrasives during grinding where the particles roll over and over. Moreover, it was stated that the particles which were doing the cutting in polishing were automatically adjusted to cut to the same depth during any stroke ; the yielding nature of the pitch ensured this. As the polisher moved in all directions and the particles cut smooth, a plane surface without grain or irregularity must necessarily result. With carriers other than pitch, the result was similar, although, for example, in the case of felt the depth of cutting was not so uniform and the final result not so good. To support his view the author stated that he had produced a fair polish on a glass lens by a soft metal tool charged with carborundum.

In the case of dry polishing, heavy uncalendared paper was pasted on to the tool and charged with the polishing agent. The mechanics of the polishing was the same as with the wet process.
                                                        J. R. C.

52. Report on Colorimetry. L. T. TROLAND (*J. Optical Soc. Amer.*, 1922, **6**, 527).—The objects of this lengthy report were (1) the clarification and standardisation of colour terminology, (2) the compilation of data fundamental to colour science, (3) the specification of standard stimuli and conditions for use in practical colour work. Colorimetry was considered from both the psychological and physical aspects. The report was divided

into sections on Nomenclature, Standard Psychophysical Data, Physical Standards, and Methods of Colorimetry and their Inter-relation. Amongst the sub-sections may be mentioned those on Standards of Energy, Distribution, and Standards of Spectral Transmission. In the former, average noon sunlight, standard artificial sunlight, normal grey light, and various standard illumin-ants were considered. In the latter, *inter alia*, it was mentioned that the accuracy with which the coloured glasses of Lovibond's tintometer were reproduced in different sets was often relatively low. Six methods of colorimetry were reviewed, spectrophoto-metry being considered the best.

An exhaustive bibliography giving ninety-eight references was appended to the report.   J. R. C.

VI.—Illumination and Illuminating Ware.

53. A Condensation Pump for High Vacua. *Times* TRADE SUPPLEMENT, January 27th, 1923.—The Langmuir pump made by the British Thomson-Houston Company was stated to give pressures below 10·5 bars and to work at the rate of 3000—4000 c.c. per second. Mercury in M is vaporised by the burner, G, and the ascend-ing vapour deflected down-wards by the baffle, A, into the condensing chamber, C, water-cooled by the pipes, D. In there it mixed with the gases to be removed and in condensing brought the latter down with it, the gas being taken out by an auxiliary pump capable of producing a vacuum of 0·1 mm. connected at E. The vessel to be ex-hausted was connected at V. The condensed mercury re-turned to the heating chamber.
                                    M. P.
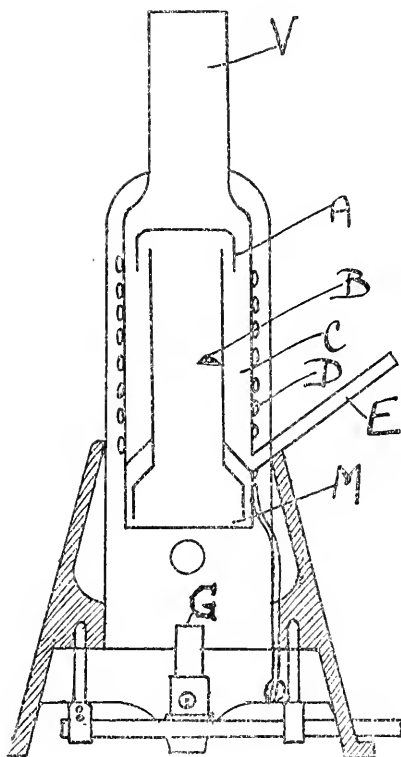
FIG. 13.

54. An Investigation (on Illumination) in a Coal Mine. E. FARMER, S. ADAMS, and A. STEPHENSON (*J. Nat. Inst. Ind. Psychology*, 1923, 5, 173).—No problem was more important in

coal mining than illumination. The difficulty in the way of in-
creasing candle power lay in the increase in weight necessary to
provide an accumulator of adequate capacity. Volunteers using a
more powerful lamp had obtained an increased output of more
than 14 per cent. as well as reducing the amount of good coal
thrown away with the dirt.

The disturbing effect of after images was dealt with and its
probable connection with miners' nystagmus was suggested. Ex-
periments indicated that a located source of light was responsible
for disturbing after-sensations which in a coal mine would interfere
with accuracy of aim and power of discrimination. A lamp covered
by a slightly opaque glass cylinder reduced the number and duration
of these after-sensations.

Data showed that the visual acuity was actually better with the
diffused light despite the reduced illumination.

The filament of the lamp was crescent-shaped. If the filament
was " loop on " to the observer, a better light was obtained than
when the filament was " end on." The lamp was hung on a prop;
hence it was suggested that the filament should be in the same
plane as the ring handle and also that suitable reflectors could be
utilised.   A. M. J.

VII.—Fuels, Refractories, and Furnaces.

55. Coal, Coke, and By-products (1913—1919). (Im-
perial Mineral Resources Bureau, Part III, 1922, 173 pp. + 10
maps. Price 7s. net.)—Contains general and statistical information
as to coal, coke, and by-products in foreign countries. F. W. H.

56. Operating Continuous Furnaces with Fuel Oil. W. G.
Edmonds (*Glass Industry*, 1923, 4, 29).—Reasons given for previous
failures with oil were the lack of consideration of comparative cost
of the installation of oil burners and gas-producers, and indifference
to the operation of the equipment when installed. For instance,
the burners in some cases had simply been two pieces of pipe, one
for the oil and the other for the compressed air or steam.

The use of specially constructed burners and the elimination of
the stuffing-box and packing had largely overcome leakage and
clogging of the burner while in operation.

The first question was that of storage, and the safest method was
to use underground tanks, in which the oil was kept hot enough to
maintain its free flowing condition, by means of steam-heated coils,
which might utilise exhaust steam. With a view to maintain a
steady oil pressure at the burners (especially when compressed air
was used to atomise the oil), a combination fuel oil pump and
heater might be used. Again, with compressed air, the storage
tank should have a drain cock to allow accumulated water to be
removed occasionally; feed lines should be $1\frac{1}{2}$ inches to 2 inches in
diameter, and kept warm by the radiant heat of the furnace in

order to dry the air and to raise the temperature.   There should be
" mains " for oil and the atomising agent on each side of the furnace,
starting at the melting end, and branch lines to the ports of the
tank and the nose of the furnace, these lines being reduced at the
side of the pipe opening into the burner, and valves placed so that
each material could be controlled at each port.   The burners should
be inclined so that the flame would strike the glass, and they should
be one or two inches outside the ports of the furnace.   A shield or
tile of galvanised iron to protect any burner not in operation was
recommended.   Where there was not a port opening at the nose
of the furnace, the burners should be arranged to keep the glass
hot enough for working.   Alternate firing should be possible, and
the air supply carefully adjusted so that the flame did not pass
through the furnace too quickly, and smoke did not pass out of
the chimney stack, from which should be seen a grey haze.   Lastly,
the supply of both oil and air should be ample to ensure perfect
combustion.   W. C. S.

**57. Fuel Saving in Modern Gas Producers and Industrial
Furnaces.** W. B. CHAPMAN (*National Glass Budget*, 1922, **38**,
No. 8, 22; No. 9, 23; No. 10, 21).—The author emphasised the
need, in producer practice, of automatic feeding, poking, and ash
removal.   In this connection, he briefly described the Hughes,
R. D. Wood, Morgan, and Chapman producers.

With skilled handling, the best mechanical producers should
give gas with average calorific value of 160 to 175 B.T.U. per
cubic foot of gas, as against 125 B.T.U. from the hand-poked
producer, whilst the rate of gasification was 25 to 30 lb. per square
foot per hour, fully twice that of the hand-poked type.   The
temperature of the bottom or hottest part of the fuel bed should
be as high as possible without fusing the ash.   The top temperature
should be sufficiently low to permit the gas to be conducted to the
furnace without tar deposition, a temperature of 540° to 600° being
usual.   When the gas was passed through a water-cooled reversing
valve, however, a top temperature of 650° would be better.   More
fuel was wasted in a producer by running with a hot top (above
700°) than from any other cause.   The use of pressure regulators,
temperature, and other recording and regulating devices were
necessary if the highest efficiency was desired.

The author advocated the study of the recuperative principle
as applied to furnaces, although the principle was not suitable for
very large glass-melting tanks.   The Stein recuperator was described.

E. E. Adams, in discussion, advocated the merits of tar-recovery
producer plants.   J. F. Rogers suggested that, to satisfy reasonable
demands, a machine making producer gas must meet the following
conditions : (1) Make a gas of maximum calorific value delivering
in the gas as much of the potential heat of the coal as possible with
a minimum allowance for the cost of gasification ; (2) use as cheap
a fuel as possible ; (3) use a coal as nearly as possible in " run-of-
mine " condition, thus avoiding crushing or screening ; (4) gasify all
fixed carbon and leave the ash free from carbon ; (5) be completely

mechanical ; (6) have an elasticity permitting of quick passage to and from high or low gasification without loss of time or efficiency ; (7) involve a low capital investment and low maintenance costs ; (8) be simple and strong in design, capable of withstanding rough usage and be easy of repair ; (9) have independent regulation of air and steam ; (10) be simple in operation so as to facilitate a change of personnel ; and (11) avoid the use of unusual and expensive materials.

W., W. Oakley stated that the only criterion for judging the efficiency of operation of a producer was the degree of uniformity in which good gas-making conditions were maintained in the fire-bed. Any device which would automatically maintain the fire-bed in a uniform condition continuously would be of very great value. None of the mechanical producers on the market would do this. All of them required that the side walls be kept free from clinkers by occasional hand poking. Accordingly, unless the type of labour and supervision was distinctly intelligent the results from mechanical producers would be very similar to those from the hand-poked variety, and very discouraging. Oakley mentioned that in one case where some hand-poked producers were converted to semi-automatics and left under the old supervision the carbon content of the ash needlessly ran as high as 50 per cent. The increased amount of dust and soot was a further item to be prepared for in the change to automatic producers. The best reasons for the installation of mechanical producers were the saving of labour and an increased rate of gasification. J. H. Matheson stated that in one factory thirty-two producers of the old type were substituted by seventeen of the same stationary type but equipped with the Chapman agitator. These producers were capable of gasifying 1500 lb. of coal per hour per 8 foot producer as against 700 lb. formerly, and resulted in great saving in fuel, labour, equipment, and valuable space. Matheson, in dealing with gas-house accessories, described his gas equaliser and soot collector (see this Journal, ABS. 1922, **6**, No. 140).   F. W. H.

58. The Recovery of Unburnt Fuel.   (*Times Trade Sup.*, 1923, **11**, 539).—It was stated that clinker from producers frequently contained up to 40 per cent. of combustible matter, whilst boiler ashes could have 20 per cent., representing in the latter case a loss of about 3 per cent. on the fuel consumed.

Three recovery methods were available : by physical treatment as in the flotation process, by electrical means as in magnetic separation, and by converting the material into low-grade gas. In this country, the first method had hitherto received most attention, whilst considerable progress had been achieved with the others on the Continent.

Flotation methods showed that as much as 45 per cent. of washed coke and 31 per cent. of washed clinker suitable for filter-bed or building purposes could be obtained from an ordinary " pan breeze " after the large clinker had been removed. Difficulties caused by the nearness of the apparent specific gravity of coke to unity had been overcome by using liquids other than water

such as brine and calcium chloride solution. A German patent
(No. 328995 D.R.-P.) employed a water-bath kept in constant
motion under pressure and containing some sand mixed with
cement. It was claimed that the clinker pores were clogged by
the cement causing the mass to sink, whilst the coke was not so
affected. Alternatively, froth flotation might be employed. A
sugar company of America had recovered in this way 61 tons of
coal of 12.9 per cent. ash content from 100 tons of ashes.

In all flotation methods wear and tear of the moving parts was
an important item. The diagram shows apparatus designed by
Weber of Wiesbaden to minimise this. A powerful current of
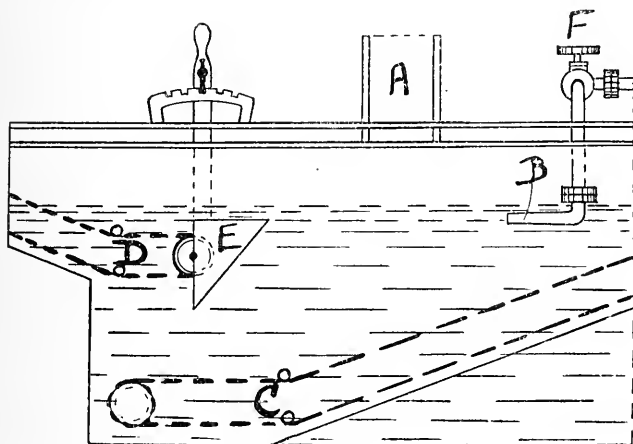
FIG. 14.

water from the nozzle, B, carries the coke fed in through A to the
trap, E, which is adjustable, whence it is removed by the top
conveyor belt D. The heavier clinker falls to the bottom and is
taken out by the belt C.

Magnetic separation depended on the fact that the bulk of the
iron oxide in the clinker was magnetic, and hence could be separated
by passing the conveyor belt over a roller inside which was a
magnetic field suitably adjusted. It was claimed that lumps of
clinker up to 3 inches in diameter would adhere to the belt whilst
in contact with the roller.

The third method employed a producer somewhat similar to a
refuse destructor, which was filled with ash and clinker ground to 0.5
inch diam. and was blown by air under 28 inches water pressure. The
ash fused and the slag was periodically tapped off. This method
gave a gas with 7.10 per cent. CO_2 and 21.27 per cent. CO.

M. P.

**59. The Mechanical Movement of Water through certain
Clays and its Control.** H. G. Schurecht (*J. Amer. Cer. Soc.*,
1922, 5, 928).—The permeability of clays to water was found to

be independent of the time, between two and ten days; that is, P was nearly constant in the expression $P = W/T$, where W was the total water passing through and T the time in days. This factor for N. Carolina kaolin was 1.55 ± 0.05, for English china-clay 1.45 ± 0.06, for Georgia clay 0.938 ± 0.07, for S. Carolina clay 0.673 ± 0.07, and for Tennessee ball clay 0.64 ± 0.08. Other investigations showed that the capillary rise of water through those clays might be expressed by the formula $H = C_h(\log T - 1.041)$, where H was the height attained by the water in time T, and C_h was approximately constant for each clay between 10 and 250 minutes; that is, it represented the movement of water through clay when it contained a certain amount of water below that required for saturation. This factor for N. Carolina kaolin was 6.67 ± 0.3, for English china-clay 7.30 ± 0.7, and for Georgia clay 4.66 ± 0.8. The greater capillary conductivity of water through primary kaolins explained why bodies containing them became drier and were released from moulds more quickly than those containing secondary clays.

The permeability factor of Tennessee ball clay was increased by 0.64 to 1.20 by adding 0.7 per cent. of caustic soda and that of Georgia clay from 0.938 to 1.72 by calcining it to $450°$. By either, or by a combination of the treatments mentioned, it was possible to improve the properties of many Georgia clays, making them more like the English china-clay in regard to permeability to water, and less liable to cause bodies containing them to crack in drying and burning.   F. W. H.

60. The Measurement of the Plasticity of Clay Slips. R. E. WILSON and F. P. HALL (*J. Amer. Cer. Soc.*, 1922, **5**, 916).— Various indirect methods previously suggested for determining the plasticity of clays and clay slips were likely to lead to erroneous conclusions, whilst the measurement of the flow or apparent viscosity of clay slips made up with a constant amount of water was shown to give misleading results. The authors emphasised the need of a quantitative measure of the physical properties commonly included in the term " plasticity " of clays.

The paper described preliminary work in this direction, work confined to a study of the properties of clay–water mixtures in the casting rather than in the moulding range. It was recommended that, instead of the vague term plasticity, the properties of a given clay, at least for casting purposes, be expressed in terms of (*a*) the water content required to give proper working consistency, and (*b*) the resistance of the resulting slip to small deforming forces such as gravity. Use was made of a modified form of the Bingham plastometer (U.S. Bureau of Standards, Sci. Paper 278), and the figures reported were (*a*) the amount of water required to give a slip of specified mobility, and (*b*) the yield value of the slip thus obtained.

The form of plastometer used consisted chiefly of a pressure stabiliser for maintaining constant pressure of several different magnitudes, a container for holding the material to be tested,

into the lower end of which was fastened a capillary and a manometer for measuring the pressure.

The method was shown to be capable of giving quantitative figures for the yield values at constant mobility which corresponded well with the customary qualitative ideas on the plasticity of clays. The amount of water required to give constant mobility varied very considerably, and did not appear to bear any definite relationship to the usual classifications of more or less plastic clays, but it was probably comparable with the shrinkage on drying.

Small quantities of acid or alkali were shown to have a negligible effect on the mobility of a clay slip, but a very pronounced effect on the yield value, the variations being greater than the difference between a non-plastic kaolin and a highly plastic ball-clay. This demonstrated the necessity for carefully controlling the hydrogenion content of the water used in making the slips. Some preliminary data were given on the effect of the additions of flint and similar non-plastic materials to clay slips, flint increasing the mobility and decreasing the yield. It was recommended that an attempt be made to agree on standard dimensions for the capillary and the desirable mobility for various purposes, and that the plastometer then be used as a standard method of test in the ceramic industry.   F. W. H.

61. The Theory of Plasticity and Its Possible Commercial Application. R. C. PURDY (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 147).—Purdy criticised many statements made by other authors regarding the theory of plasticity and its connexion with colloids, and considered they were in line with the fallacies taught by P. Rohland in 1913, and still being advanced by some physical chemists.

The terms " sol " and " gel " had application in the physical chemistry of clays only in a remote sense; they were pictorial terms and not really applicable to the whole clay mass. Rather than " sols " or " gels," Purdy pleaded for the use of the terms " deflocculated " and " flocculated." They left out of consideration the solution ideas and referred only to dispersion and precipitation of discrete clay particles without any hydration, hydrolysis, coalescence, or other physical chemical alterations. Clays did not form typical colloidal solutions; only a small portion of any clay roughly approximated such solutions and that state was not essential to plasticity. Any or all portions of any clay, the coarser grains of which were rich in " clay substance " (as determined chemically), would be about as plastic and have a strength equal to the clay before removal of the portions which approached " true colloidal solution."

The author granted that the fine clay particles came under the classification of colloid, but since the particles in clays were discrete and did not coalesce, and since the majority of them in most plastic clays were too large to be styled colloidal, why not characterise them as " particles," rather than as colloids. In his opinion, plasticity was the result of purely physical conditions and proper-

ties, adsorption, solution, molecular attraction, and high surface tension. These caused the particle, when wetted, to hold a water-saturated film. For the mass to exhibit plasticity, the particles must not be separated one from the other beyond the range of molecular attraction, which range was sufficient to permit each to retain its maximum water envelope. Experiments had shown that the volume of water required to render a clay mass plastic was equal to the volume of water required to fill the pores when the formed mass had been dried, plus the water required to give each and all particles (or bundles of particles) its maximum water film. This salt solution film was the " slippery medium " and when the mass was dried these salt coatings were the cementing agents, and when subjected to heat treatment they were the sintering media. Flocculation and deflocculation occurred in response to relative difference in surface tension of the excess water. The author described this difference as a difference in potential, and his conception was that clay particles were flocculated when the potential of the water envelopes was less than that of the excess water, and they became deflocculated when the potential of the water envelopes was greater. The greater surface tension of the water envelope not only resulted in deflocculation, but also required less excess water to give the clay mass the same degree of plasticity. When the mass was mixed with a sufficient quantity of water to allow free movements of the particles, a condition known as " slip," the particles would become flocculated as the surface tension of the excess water was increased. That explained why a small portion of salt caused deflocculation (it all went into the films by adsorption) and excess salt flocculation once more.   F. W. H.

62. Porosity. VII. The Determination of the Porosity of Highly Vitrified Bodies. E. W. Washburn and E. N. Bunting (*J. Amer. Cer. Soc.*, 1922, **5**, 527).—For bodies with a low porosity a McLeod gauge type of porosimeter was described. The following method of procedure was given : The apparatus, as shown in Fig. 15*a*, is connected to a drying tube. Pour 250 c.c. of mercury into the levelling bulb, open the stop-cock, and raise the levelling bulb until the apparatus is filled with mercury to a short distance above the stop-cock. Close the stop-cock, lower the levelling bulb until the mercury falls to the bottom of the porosity tube stem, and then raise the bulb to the level of the bottom of the porosity tube and clamp it in a support. Open the stop-cock and when the mercury has fallen to equilibrium release the rubber bands, open the apparatus, insert a reference test-piece, put the apparatus together, and again fasten it in place with rubber bands. Pour some mercury into the mercury seal and raise the levelling bulb until the apparatus fills with mercury as before. Close the stop-cock and lower the levelling bulb until the mercury falls below the bottom of the test-piece. Raise the levelling bulb to the level of the stop-cock and when the mercury in the apparatus has come to rest, open the stop-cock, thus expelling the gas from the capillary tube. Close the stop-cock and lower the levelling

bulb to the level of the bottom of the test-piece, then open the
stop-cock slightly and allow the apparatus to fill slowly with dry
air.   Allow the test-piece to soak in the dry air until equilibrium
is attained.   Again raise the levelling bulb until the apparatus
fills with mercury, close the stop-cock and lower the levelling bulb
until the mercury drops below the bottom of the test-piece.   Allow
the test-piece to soak in a vacuum until equilibrium is attained.
Raise the levelling bulb until the two mercury surfaces are on the
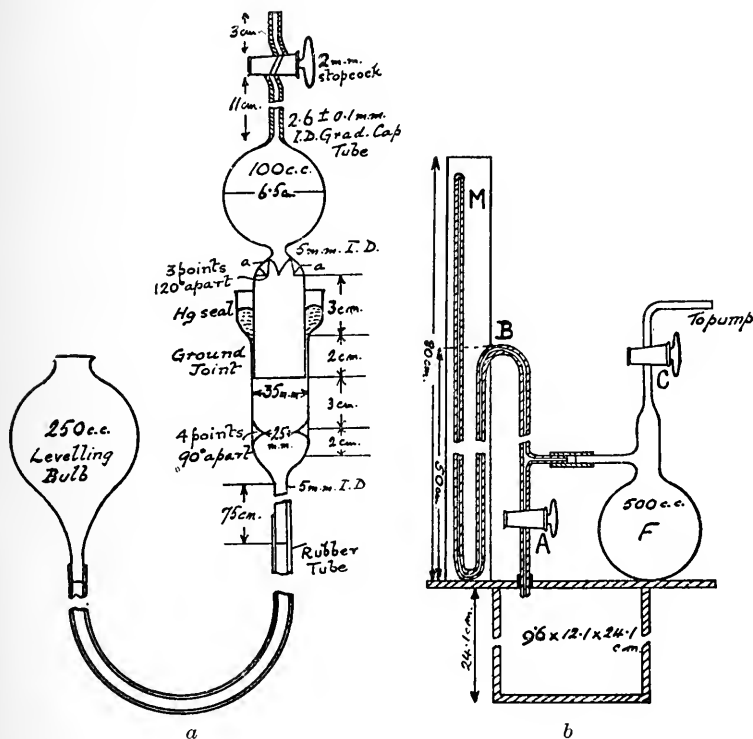
FIG. 15.

same level, and read the volume of air in the graduated capillary
tube.   Lower the levelling bulb to the level of the bottom of the
test-piece and open the stop-cock.   Remove the reference test-
piece and replace by the test-piece for examination.   Repeat oper-
ations subsequent to introduction of test-piece as before.   By
subtracting the reading obtained with the reference test-piece
from that obtained with the actual test-piece the pore-volume,
V_p, of the latter is obtained.   The bulk volume, V_B, of the test-
piece is obtained by the use of an accurate mercury volumeter.

Results showed that the accuracy obtainable was 0.01 to 0.02 c.c.
on the pore volume.

The percentage porosity, x, was calculated directly from the

3—2

equation $x = \dfrac{100 V_p}{V_B}$.   The use of this simple equation was justified
provided the apparatus was constructed so as to fulfil the following
condition :

$$\frac{V_c^2}{V_F} 0{\cdot}01 \text{ c.c.,}$$

where V_c was the volume of the measuring tube and V_F was the
total free volume of the apparatus when it contained the test-
piece. Tests on eight pieces of electrical porcelain indicated a
porosity of $0 \pm 0{\cdot}01$ per cent. and the results were confirmed by
dye-penetration tests.

A simple and rapid apparatus for measuring the porosity of
full-sized bricks by the "general method" (this Journal, ABS.,
1922, **6**, 129) was described and is shown in Fig. 15*b*. The con-
taining vessel was designed to take the largest size standard brick
in the dry state, whilst for smaller bricks unoccupied space was
filled with glass plates. It was made of any suitable non-porous
material (glass, metal, porcelain), and the cover was of similar
material ground to give an air-tight joint when greased.

With the brick in place and both stop-cocks open, the mano-
meter was read, giving B; then stop-cock A was closed and the
flask, F_1, evacuated to some low pressure, P_1. Stop-cock C was
then closed, the manometer read again, giving P_1, and the stop-
cock A opened. When pressure equilibrium was attained, the
manometer was read a third time to give P_2. The percentage
porosity, x, was calculated from the expression $x = 100 \Big[\dfrac{(P_2 - P_1) V_1}{(B - P_2) V_B} -$
$\dfrac{(V - V_g - V_B)}{V_B} \Big]$, where V_1 was the volume of the flask, F, from
stop-cock C around to stop-cock A, and including that portion of
the manometer tube from the mercury surface in B around to the
side-arm of the flask; V, the volume of the containing vessel and
that part of the capillary up to stop-cock A; V_g the volume of
any glass plate used for reducing the free volume of the containing
vessel. The bulk volume, V_B, of the brick could be calculated
from linear dimensions or determined with a water volumeter of
the overflow type, the brick being first dipped momentarily into
hot paraffin or rubbed thoroughly with vaseline to close the surface
pores.   F. W. H.

**63. Note on the Relation of the Structure of Clay Grains
to the Plasticity of Clays.** H. G. SCHURECHT (*J. Amer. Cer.
Soc. Bull.*, 1922, **1**, 153).—It was undoubtedly true that the fine-
grained kaolinite aggregates, or "bundles" of clay particles as
Purdy (this Journal, ABS., 1923, **7**, 33) called them exerted an
important influence on the plasticity of clays. Contrary to Purdy's
statement, since the author had found that the plasticity of many
clays was affected by the initial alkalinity or acidity of the clays,
and since those clays having the larger proportion of extremely
fine-grained *kaolinite* particles were more affected by electrolytes

than those composed of coarser individual particles, it appeared to him that the fine particles in clay did play an important part in the plasticity of many clays, although it was not the only factor influencing plasticity.

It was assumed in the following tentative conclusions, based on a limited amount of laboratory work, that all other things were equal except the two factors cited in each case. (1) Clays composed of loosely cemented aggregates of fine-grained *kaolinite* were more plastic than those containing firmly cemented aggregates of kaolinite particles (that is, aggregates not disintegrated by agitation with water), and those composed of coarse crystalline *kaolinite* particles. (2) Clays composed of flocculated aggregates of fine-grained *kaolinite* were more plastic than those composed of deflocculated particles of *kaolinite*. (3) Clays consisting of aggregates composed of extremely fine-grained *kaolinite* particles were more plastic than those in which the aggregates were composed of coarser *kaolinite* particles. (4) Clays composed of flocculated aggregates of fine-grained *kaolinite* were more plastic than those composed of cemented aggregates of fine-grained *kaolinite*. F. W. H.

64. Loss on Ignition, and Porosities of Kaolins, Clays, and Bauxites, etc. A. BIGOT (*Compt. rend.*, 1922, **174**, 1232).— Specimens of kaolins, clays, and bauxites were prepared from powder passing through a No. 200 mesh. The loss on ignition and the porosity were determined, an oil of known density being substituted for water when making determinations of the porosity of the clays and kaolins.

The colours of the samples were found to change after heating to 200°. The losses were small up to 300°. One bauxite containing 25 per cent. of combined water lost almost half of this amount at 300°, whilst another sample, containing 15 per cent. of water, lost only 1 per cent. At 600°, the different samples lost somewhat similar quantities of water, some 13 to 14 per cent. Those with greatest combined water lost the excess around 300°. Bauxites and kaolins formed a definite hydrate decomposing at 600°, and retaining some 14 per cent. of water.

Between 300° and 400° the clays and kaolins underwent a definite change, becoming hard and resistant to water, cold or boiling, slightly acid or alkaline. V. D.

65. The Action of Heat on Kaolins, Clays, etc. A. BIGOT (*Compt. rend.*, 1923, **176**, 91).—Samples of raw kaolins, clays, and infusorial silicates were dried, crushed to pass mesh 200, and two series of specimens prepared (*a*) with wet paste, and (*b*) from partly dried powder, moistened with 4 to 8 per cent. by weight of water, compressed under pressures varying from 375 to 400 kg. per sq. cm. These specimens were heated, and maintained at definite temperatures for five hours, after which time they were examined for hardness and resistance to breaking up in water, cold or boiling, to 10 per cent. sulphuric acid solution, or to 10 per cent. solution of soda.

The two types of specimens prepared from one original material behaved quite differently. A kaolin in the form of wet paste, maintained at 380° for five hours, did not break up in cold or hot water, in acid, or in alkaline solution. It had become hard, and durable. The same material prepared as a damp powder, submitted to pressure, and then treated to the same heating had not hardened sufficiently, but after heating at a temperature of 450° for five hours it had become hard and resistant to the action of water, acid, or alkali.

A clay, containing 25 per cent. of alumina, hardened at a temperature between 400° and 450°, if prepared as a wet paste; but it was necessary to maintain it at 500° to ensure hardening, when prepared from partly dried powder.

Bauxites, and infusorial silicates behaved similarly. A schistose clay hardened at temperatures of 600° and 800°, respectively, for the two types of specimen, although it was necessary to heat the compressed powder type at 1000° in order to render the material sufficiently hard to resist boiling water, acid, and alkali.

Wet paste samples made from a kaolin of which the colloidal plasticity was 4·25 were maintained at a temperature of 450° for five hours, the material was then crushed, passed through mesh 200, and the colloidal plasticity of a paste made from this powder was 1·78. Samples of the kaolin hardened at 500°, and when the crushing, agglomeration, and heating at 500° were repeated several times, the hardening and decrease in colloidal plasticity continued, although to a less extent. Similar experiments were made with various samples, and it was evident that, on heating, plastic ceramic materials first hardened without dehydration or change in volume, this hardening being due to partial peptising of the colloids present. After dehydration, and above 700°, physical changes occurred, accompanied by shrinkage, and the samples continued to harden whilst the colloids disappeared. Non-plastic materials only hardened once, at a temperature about 1000°, after complete dehydration at 650–700°.   V. D.

66. The Influence of Grinding and Burning on the Characteristics of Silica Brick (A Discussion) (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 184).—R. M. Howe (see this Journal, Abs., 1922, **6**, 216) stated that the time of grinding had very little influence, although the temperature of burning was extremely important, on the modulus of rupture of silica brick. Different opinions were expressed regarding the resistance to spalling of light-burned and hard-burned silica bricks. Howe stated that hard-burning was justified by the results obtained in practice when the bricks were exposed to the highest temperature. At lower temperatures, however, hard burning was of no advantage and might sometimes be a disadvantage. Hard-burned silica bricks gave very good service in open hearth roofs and coke-ovens when compared with those which were light burned. On the other hand, light-burned sand rock bricks gave extremely good service in furnace roofs where lower temperatures were involved.   F. W. H.

67. The Influence of Heat on the Microscopic Properties of Silica in its Different Mineral Forms. J. T. ROBSON (*J. Amer. Cer. Soc.*, 1922, 5, 670).—A study of the effect of heat at cones 13 and 14 on the index of refraction of the four common mineral forms of silica, namely, sand, *quartz*, *chalcedony*, and French flint, the last-mentioned being a nodular form of silica which occurred as pebbles along the Atlantic coasts of Europe and Greenland.

The samples were burned in saggers, at the desired temperatures, for four and a half hours. The effect of heat on the index of refraction of the different forms of silica was given as follows :

Material.	Before heating.	After heating to cone 13.	to cone 14.
Sand	1·545	1·545	1·509
Quartz	1·545	1·545	1·517
Chalcedony	1·540	1·527	1·495
French flint	1·527	1·487	1·487

The results showed that above cone 13 both sand and *quartz* tended to form *cristobalite*, which had an index of refraction of 1·487. The low index of refraction of the French flint originally was due probably to the fact that before it was ground the pebbles were calcined at about 1000°. At cone 13, the French flint changed entirely to *cristobalite*. The experiments did not indicate whether or not French flint was entirely converted to *cristobalite* below cone 13. At cone 14, the *chalcedony* was almost entirely inverted into pure *cristobalite*.

The *quartz* used in these experiments was much coarser than the other samples and the *chalcedony* much finer than the others.

R. Rieke (*Ber. deutsch. Keram. Ges*, 1921, 2, 169), using a portion of the above original samples, had studied the speed of transformation into *cristobalite* by burning the samples to 1430° and noting the changes in specific gravity. He obtained the following results :

Material.	S.G. before burning.	S.G. after burning.
Sand	2·67	2·49
Quartz	2·66	2·49
Chalcedony	2·66	2·32
French flint	2·58	2·28

Cristobalite had a specific gravity of 2·32.　　　　F. W. H.

68. The Influence of Heat on the Microscopic Properties of Silica in its Different Mineral Forms (A Discussion) (*J. Amer. Cer. Soc. Bull.*, 1922, 1, 348).—H. Insley stated that Robson's article (see preceding ABS.) was apparently based on the assumption that there was a gradual change from one polymorphic modification of silica to another, contrary to modern theory. Robson gave the index of refraction of *quartz* as 1·545 before heating and as 1·517 after heating to cone 14 and appeared

to imply that 1·517 was the index of refraction of a pure homogeneous crystalline modification of silica with physical properties intermediate between those of *quartz* and *cristobalite*. This was doubtful. The conclusion " that French flint and *chalcedony* were both transformed into *cristobalite* before sand and *quartz* " might be true, but the author did not prove it, since he adopted, as indicated previously, a possibly incorrect conception of the crystalline transformation.

J. T. Robson, in reply, stated that the phenomenon of gradual polymorphic transformation of the aggregate mass under examination was demonstrated by S. McDowell when he showed the effect of repeated burning on the constitution of silica brick. A portion of this table, stating the volume per cent. after firing, was given as follows :

Mineral.	One firing.	Three firings.
Quartz (and silicates)	25	12
Cristobalite	71	58
Tridymite	4	30

Attention was directed to the decrease in the volume of *quartz* after the third firing, likewise the variation in the volumes of the *cristobalite* and *tridymite*. He did not claim that there was a pure homogeneous crystalline modification of silica with physical properties intermediate between those of *quartz* and *cristobalite*, but that the aggregates did have an index corresponding with the mean indices of the discrete particles of which it was constituted.

F. W. H.

69. Comparison of Hot and Cold Modulus of Rupture for Silica Brick. E. N. McGEE (*J. Amer. Cer. Soc.*, 1922, **5**, 888).—The author set out to investigate whether or not the hot and cold strengths of silica bricks were comparative and further to obtain definite information on the cross-breaking strength of silica brick at temperatures encountered in coke-oven practice. A cylindrical furnace was used for the hot tests, fired by two tangential burners. The test bricks rested on " knife-edges " of carborundum about 6 inches apart. A silfrax tube, 5 inches long, was laid across the middle of the brick span and served as the knife edge carrying the pressure which was exerted by a beam with a can containing water. To reach the testing temperature of 1350° about six and a half hours were required and a heating schedule was given. After one hour at 1350° the load was increased until the brick broke.

Although the results obtained did not permit of definite conclusions being drawn regarding the relation of the hot modulus of rupture to the cold modulus or cold crushing tests, other conclusions were obtained. The cross-breaking strength of a brick at 1350° was approximately one-third the strength at atmospheric temperature. Erratic heating of the brick led to breaking at very low pressure. The cross-breaking strength decreased as the temperature increased, from 950 to 1680 lb. per square inch when

cold to 130 to 189 lb. per square inch at 1350°. The hot tests appeared to give results comparable in most respects with the cold tests, and for routine tests the cold test was recommended on the ground of time economy.   F. W. H.

70. Physical Defects in Tank Blocks (A Discussion) (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 239; this Journal, ABS., 1922, **6**, No. 145).—There was a consensus of opinion that small tank blocks were preferable to large. H. L. Dixon believed that the decoloriser now in use was much worse in its effect on blocks than was manganese. Dixon and others favoured the use of cullet in starting a tank, and considered nine or ten days much too short a period in which to start a tank and obtain glass from it. G. Aurien stated that his firm took thirty days to bring a tank to working condition.   F. W. H.

71. Chrome Refractories. J. S. McDOWELL and H. S. ROBERTSON (*J. Amer. Cer. Soc.*, 1922, **5**, 865).—A compilation from the more important data relating to the properties and uses of chrome and chromite refractories, together with comprehensive bibliography.   F. W. H.

72. The Handling, Storing, and Setting of Glass Pots (A Discussion) (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 247).—H. L. Dixon stated that one important feature was omitted from the paper (this Journal, ABS., 1922, **6**, No. 143). Whenever a pot was set, openings in the siege should be filled so that glass would not penetrate it. The life of the furnace depended to a large extent on this factor. Every pot had a concave bottom, and it was essential to ensure that any sand placed upon the siege supported both the centre and outside of the bottom. J. H. Forsyth stated that in his experience satisfactory results had been obtained by elevating the pot bottom above the siege.   F. W. H.

73. Why are Open Pots Used in Europe and not in the United States ? (A Discussion) (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 340).—J. C. Hostetter stated that he had melted many open pots of optical glass containing 45 to 55 per cent. of lead oxide with no indication of reduction of the lead and melting was much quicker than in the closed pot. H. W. Hess agreed that this was quite possible, but the use of open pots for lead-containing glasses depended on the size of the pot and the area. Using tanks for lead oxide-containing bulb glass, he found great difficulty at times, due to the apparent flowing of glass layers of different density over the surface of the tank. Melting in small pots during the night and working during the daytime was the method usually employed. A rise of temperature during the working of lead glass always caused trouble. He had seen gold and selenium ruby glasses made in tanks.   F. W. H.

74. The Best Type of Crowns to be Used Over Glass Tanks (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 339).—It was suggested

that the use of a flat crown was a feasible proposition. It gave a smaller radiation surface and could be repaired in spots without disturbing any of the rest of the arch. On the other hand, there would probably be a tendency for joints to open, whereas with the ordinary arch held by buckstaves the bricks were held tightly together and there was little leakage of gases through the crown.

F. W. H.

75. The Water Cooling of Glass Tanks (A Discussion) (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 310).—Water-cooling undoubtedly prolonged the life of tank-blocks, but impure water, producing scale and sediment, might result in the water-coolers becoming insulators and increasing the rate of corrosion. The general opinion was against water-cooling as at present practised, since it entailed costly constructional work, considerable expenditure of water, and greater loss of heat from the furnace. The cost of replacing tank-blocks might very conceivably be less than any system of water-cooling, and the real requirement was a less corrodible block.   F. W. H.

76. A Water Cooling Method for Furnace Walls. C. S. STAFFORD, 25, Foyle Road, Blackheath, London (Brit. Pat., **183572**, April 25th, 1921).—In order to protect the wall of a furnace from injury by water or steam, which is applied directly
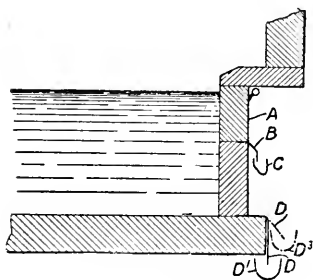
Fig. 16.

to the outer face of the wall to cool it, this outer face is sprayed or otherwise treated, so as to produce a continuous layer, with molten metal, vitreous enamel, or glazing-composition. As shown, the external face of the wall of a glass-melting furnace is sprayed with the water-proofing material, A, and provided with a drip-plate and gutter, placed in any one of the positions shown at BC, DD^1, or D^2D^3, to carry away the cooling-water. Before applying the water-proofing layer, the outer face of the wall may be rendered less porous by covering it with a thin coat of a non-shrinking cement having the same coefficient of expansion as the material of the wall. According to the Provisional Specification, the wall may be provided with metallic heat-radiating elements, which are placed in position before the blocks are sprayed.

H. G. C.

77. Glass Making in an Electric Radiation Furnace. V. M. SAUVAGEON (*Chim. et Ind.*, 1922, **7**, March).—Preliminary trials with furnaces of the resistance type, in which the current passed through the glass, had shown that the heat was too much concentrated, giving rise to trouble at the working end and to rapid wear of the tank sides. The inclusion of a heating circuit in the crown was found to be beneficial. Thus a furnace

of the first type 4·5 m. × 2·0 m. reached 1400° on 300 kw. and produced 1500 kg. of glass per day, whilst one of the second type
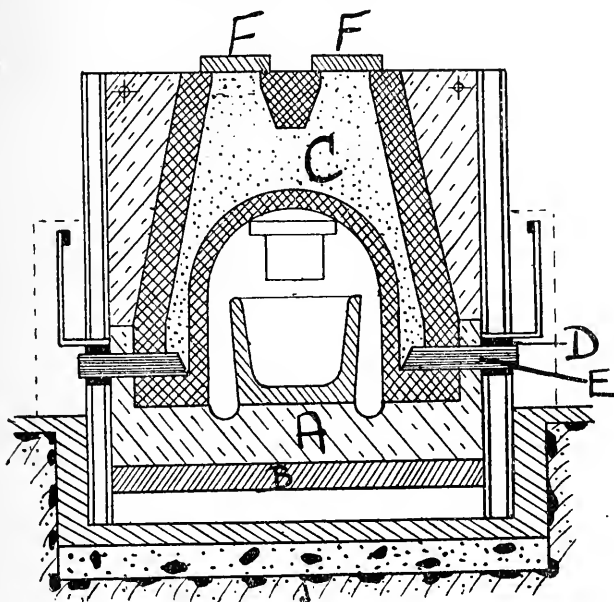
FIG. 17.
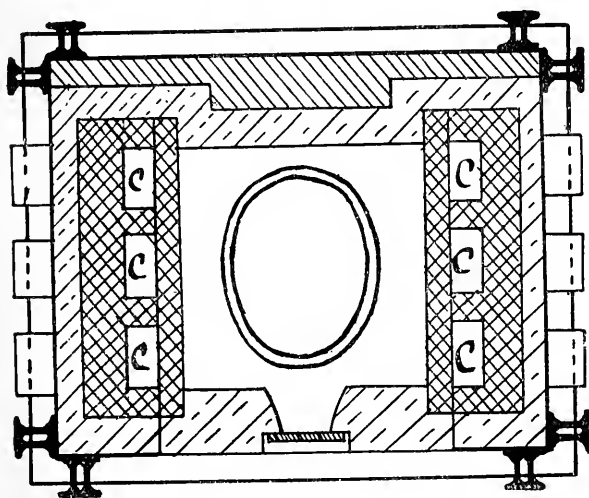
FIG. 18.

2·95 m. × 1·0 m. reached 1500° on 170 kw. and produced 900 kg. per day, this glass being of better quality than the first. The heat

was again concentrated too much in the glass itself and the furnace finally designed used only heat radiated from the sides and crown, no current passing through the glass. This furnace was of the pot type, measuring internally $1\cdot22\times1\cdot37$ m. and was $1\cdot16$ m. high (to the top of the crown), and housed a pot holding 400 kg. The furnace was in two parts, the lower consisting of the siege block, A, mounted on brickwork, B, permitting free access of air to its lower surface. This part took no current. The upper part consisted of the sides and crown containing the "electric chambers," C, through which the current was passed. The chambers, three in number, were built of a magnesia mixture containing at least 7 per cent. of iron oxide. This material had been investigated and found to be very refractory, a good conductor of heat and of good mechanical strength. Through canalisations, D, at either side of the chamber were placed the carbon electrodes, E, capped externally. The chambers themselves were packed with the resister, consisting of small grain petroleum coke which on the passage of the current was converted into graphitic carbon. The top of each chamber, F, was removable to permit of access to the resister when the furnace was running in order to poke it if necessary, or to replace burnt carbon. The arch and sides of the furnace were made exceedingly thick to reduce radiation losses.

Single-phase alternating current was fed to the furnace through a transformer and voltage regulator, ensuring a voltage constant within very narrow limits and very steady running.

In heating up, the furnace was taken up slowly in five days from 25° to 1000°, and was then cooled to room temperature to allow the pot to be introduced. It was then taken up to 850° in six days, at which temperature the current consumed was 42 kw. In two more days the temperature was 1070°, and the pot was then filled with cullet. This was melted and the temperature had reached 1425° in a further one and a half days. A window glass batch was then run for eighteen days between 1350—1400°, the temperature being allowed to drop each time for working out. The power absorbed was never more than 134 kw., and was generally in the neighbourhood of 100 kw. The average production over the best period was $2\cdot11$ kg. glass per kilowatt-day. Much less trouble was caused by failure of current, which occurred several times, than would have been occasioned in a gas-fired furnace by the corresponding trouble. Electrodes were replaced when necessary without cutting off the whole current, but had they been water cooled such replacements would probably have been unnecessary. With the necessary minor adjustments the author regarded the design as having a commercial future, for example, in the production of glasses of high silica content. Such a glass containing 82 per cent. SiO_2 had indeed been melted during the trials. It was suggested that in a tank furnace of similar design even better results might be reached. Probable figures were $7\cdot11$ kg. of glass per kilowatt-day corresponding with $7\cdot11$ kg. per 800—1500 kg. of coal in a producer fired furnace, though these estimates would have to be checked practically.   M. P.

78. Gas Producer- and Furnace-design for the Glass Industry. R. SCHNEIDER (*Glashütte*, 1922, **52**, 625, 642, 657, 674, 689, 707, 723, 755, 771, 787).—The author's rules for the layout and building of producers and furnaces were given.

Producers.—Where several producers served one or more furnaces a collecting flue of sufficiently large section was employed, serving to mix and render the gas homogeneous and supplying it at a constant composition and pressure to the furnace. This flue also served to check the speed of the gas, so throwing down dust and condensing tar and water. The bottoms of this flue and of all flues leading to the furnace were given sufficient head and provided in suitable places with tar pockets. To provide a very pure gas, wide iron tubes were placed in the collecting flue through which
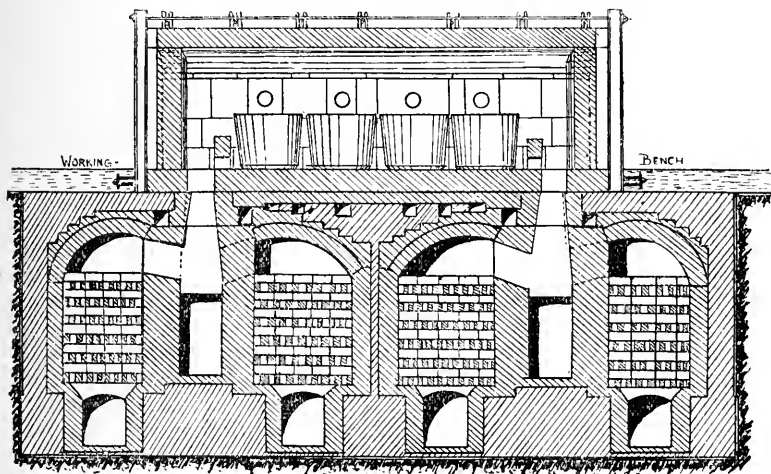
FIG. 19.

circulated water or lime water. Many modern producer plants were constructed with special tar-extracting apparatus, and in this case the fuel was burnt at a lower temperature (400—500°) in order to obtain phenol, paraffin, etc., as by-products.

Furnace Plant.—In building the usual type of long pot-furnace, the long axis of the furnace (and consequently of the building) was placed north–south, in order to allow the east and west sides to be used for working. The building was provided with high walls, with large window openings and a steep roof, which acted somewhat as a chimney. The producers were placed on the side of the building to leeward of the prevailing winds, and at a sufficient distance to allow for the introduction of the collecting flue, with enough room for cleaning it. The chimney was built near the producers with as short a connecting flue as possible, whilst it was provided with special flues for burning out, joining it to the gas delivery flues. For pot furnaces and day tanks, the reversal

valves and regulating damper were placed preferably in succession between the producer and the furnace, or less usually side by side at the front of the furnace.   In the former case, the effect of regulation on the furnace could be easily seen, and with this arrangement it was better to house the valve and damper wholly or partly in a special wing of the building and not in the shop. For continuous tanks the working floor faced either north or east. When the regenerators lay in some degree under the tank, the reversal valve and damper were placed in front of the filling-on platform.

Should the furnace be built on stable, dry clay, no special foundations were necessary; in other cases a special foundation of 25—60 cm. of pounded clay was laid.   The furnace walls up to about 1 m. from the bottom edge were of second quality fire-brick, above this point of first quality, whilst brick of at least equal quality was used for the upper part of the sub-structure and parts of the super-structure in contact with furnace gases. All brickwork was made with the closest possible joints, using a very refractory and fluid mortar.   Vertical regenerators, although somewhat more expensive to build, were better than horizontal ones, and gave a fuel saving of 10 per cent.   The regenerators were walled within with firebrick with close joints, the wall having a smooth, clean exterior, and an outer wall of red brick was built at a distance of 7—8 cm.   Piercing the two walls were built short flues about 12×12 cm., one some 30 cm. from the bottom, the other at the top of the regenerator.   These were intended for inspection purposes, and were closed by suitable slabs.   The firebrick wall and connecting flues were strongly built in order to allow the space between inner and outer walls to be filled with fine, dry, washed sand without any leak into the regenerator.   Pockets of pot furnaces were similarly closed, with the difference that, where possible, the inner wall consisted of a large fireclay block, 20 to 25 cm. thick, in the middle of the lower portion of which was a 20×20 cm. opening, closed with a somewhat conically-shaped stone which projected some 6 cm.   In front of this wall, at a distance of 10 to 15 cm., was built the red brick wall, without opening, and the intervening space was filled with fine, washed sand.   This type of walling prevented heat losses, whilst in the case of the pocket, glass flowing down from the furnace could be removed by taking down the outer wall, removing the stopper, and either letting the glass flow out or raking it out.   The four flues lying between the reversal valve and the furnace were provided at suitable points with 60×60 cm. openings in the roof, these being closed by iron plates, well luted in with clay, and covered at the edge with sand.

There were three types of regenerative furnaces, namely, (1) Bütten-, (2) the so-called "Slit-," and (3) Schneider-furnaces. The last-named form (see Fig. 19) allowed the air and gas to pass into the combustion chamber by slits at each end of the sole of the furnace, and not at points between the two rows of pots.   By this arrangement the corner pots were not left cold, whilst, when

carefully constructed, the life of the ports was at least twice that of the "slit" furnace. The Schneider furnace worked more regularly and somewhat more economically than the other forms, since it was about 30 cm. narrower than either. The regenerators in the third type lay only partly beneath the furnace and in a direction at right angles to that of the regenerators of the other two forms. This allowed of the simplification of gas- and air-valves, whilst it prevented the crossing of flues, or the carrying of these under the regenerators, to the reduction of the size and efficiency of the latter. The pots were set through openings in the long side of the furnace. A. C.

79. An Electric Furnace for the Melting of Quartz Goods. W. SCHUEN (*Ker. Rundschau*, 1923, **31**, 12).—Quartz was melted to a cylindrical-shaped mass round an electrically heated carbon tube. At the stage of development then attained, only pieces of quartz so shaped could be worked and then by processes adapted from the glass industry.

The electrical resistance consisted of a tube of 1 m. length, 35 mm. external diameter, and 25 mm. internal diameter, made of the purest possible electrode carbon. At each end of the tube an electrode consisting of a thick block of carbon was arranged to make good electrical contact with it. The electrodes were surrounded by strong iron bands, and the cables were joined to the electrodes by detachable strong iron connecting pieces. The resister and electrodes were built into a furnace capable of rotation. The furnace consisted of a strong iron cylinder lined with a glazed fireclay cylinder. Asbestos was placed between the iron shell and the electrodes to prevent short-circuiting. Only alternating current could be used. The voltage was 40 and the current 800 to 1000 amperes. In twenty minutes 18 to 23 kg. of sand could be melted with a current consumption of 7·5 to 8 kw./hours. Sketches of the furnace were given.

A piece of waste quartz tube was slipped over the carbon resister. Sand was then filled in to such a height that the top electrode could not rest on the edge of the furnace but rested on top of the sand. The silica and the carbon reacted, with the formation of silicon carbide and carbon dioxide. Any gas developed could escape only with difficulty and so a protective layer was formed between the glowing resister and the soft quartz. To counteract the high gaseous pressure, a hand-operated lever was used to maintain electrical contact between the resister and the electrodes. The melting process was concluded in twenty to thirty minutes and then the quartz had to be worked quickly. H. W. H.

80. Operation of Lehrs (A Discussion) (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 249) (cf. this Journal, ABS., 1922, **6**, No. 158).—H. E. L. H. Adams objected to the phrase used by Frazier when he spoke about "the temperature at which the strain was introduced," and claimed that there was no strain in glass until it was at a low temperature. A. R. Payne, in reply, stated that he used a pressure of 5000 lb.

per square inch in the making of tumblers. There was much more trouble experienced in obtaining satisfactory annealing with this ware than with articles of the same size and weight made with low pressure. He felt sure that strain was introduced, when the plastic glass was compressed, at a temperature above that of the annealing region, quite independently of any due to chilling.

It was further stated that in pressing spectacle lenses by a quick, hard action, the lenses had a greater tendency to show cracks on the surface due to quick cooling than when a slow, squeezing action was used.   F. W. H.

81. Modern Glass Factory Equipment. W. S. MAYERS (*The Glass Industry*, 1923, **4**, 21).—Lehrs gave the most fertile field for improvement in the glass factory, and were generally of low efficiency due to small combustion chambers and exit channels for waste gases. The development of the modern muffle lehr was traced, but the difficulty of selecting a medium for the muffle wall was emphasised. The roof should be flat and only a few inches higher than the tops of the tallest article passing through; 10 feet was the widest possible dimension on account of mechanical strength, whilst too narrow a lehr occupied too much floor space, to avoid which some attempts had been made to use vertical runs for lehrs. In any case, a closed chamber in the heating and part of the cooling section gave a saving in fuel and a more easily controlled temperature, a common fault in muffle lehrs being the sudden change in temperature gradient at the junction between the fire-box and cooling section. The use of electricity presented the advantages of cleanliness and absolute control, but was too expensive for ordinary use.

In lehr operation, the time usually taken for heating and cooling varied from four to eight hours in existing installations, although recent tests had shown that soda-lime pressed tumblers which had been cooled by air jets would withstand the same rigid factory tests as ware taken through the lehr in four or five hours. At the same time, if pressed ware had been allowed to cool considerably before reaching the lehr, then the heating period would have to be lengthened to avoid breakage. A new type of time- and fuel-saving lehr for blown ware offered an attractive field for designers.

The use of the pyrometer was increasing, if only to indicate the best working temperature and not the actual true temperature of the article. Tests on the finished product might be made with the polariscope which would not give entire information; or by subjecting the article to violent temperature change.   W. C. S.

82. A Tungsten Furnace. K. T. COMPTON (*J. Optical Soc. Amer.*, 1922, **6**, 910).—Sheet tungsten was bent into the form of a cylinder and the ends were clamped to steel blocks by molybdenum clamps. The steel blocks were in turn fastened to water-cooled brass tubes by which the current heating the tungsten cylinder was lead in. A central electrode of tungsten wire ran along the axis of the cylinder. By adjusting the length of this wire it was possible to secure equal potential drops along the furnace and the filament so that they acted as equipotential electrodes.   J. R. C.

83. A Constant Temperature Oven. C. M. MACKALL, G. E. MILLER, and E. E. REID (*J. Ind. Eng. Chem.*, 1923, **15**, 121).—

The oven consists of a glass tube, AB, 3.5×50 cm., sealed at one end and closed at the other either by a ground-in stopper with a tap for evacuation, or by a similar one carrying a short and long tube through which a current of gas can be circulated. The heating is carried out by vapour from the flask, H, and the oven is insulated by a thick 85 per cent. magnesia jacket, ST. To enable the contents of the oven

FIG. 20.

to be readily manipulated, a small low voltage electric bulb, C, is placed at the closed end of the tube and is controlled by the switch, R.   M. P.
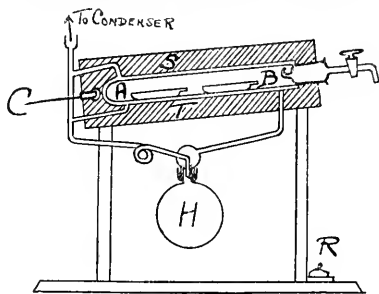
84. An Electric Flue-gas Tester. C. O. FRIEDRICH (*Chem. Zeitung*, 1922, 848).—The method was based on the difference in heat conductivity between CO_2 and the other possible constituents of flue gas. Since its heat conductivity was only half those of air and CO_2, any variation in composition of the flue gas gave an appreciable
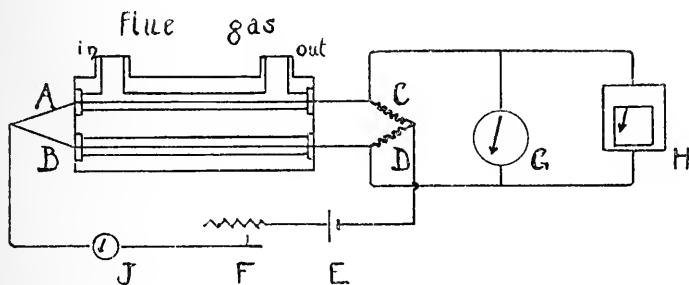
FIG. 21.

difference in heat conductivity; so that a hot platinum wire placed in a steady current of flue gas did not cool so rapidly when the CO_2 content increased. Therefore, with connections as shown in Fig. 21, and with a balance wire with steady temperature conditions, an instrument had been designed of strong build, which could be used to give constant readings automatically. A small battery, current meter, and adjustable resistance were also required, and the gas was drawn through the apparatus by a water suction pump. W. C. S.

85. The Industrial Treatment of Fumes and Dusty Gases. W. E. GIBBS (*J. Soc. Chem. Ind.*, 1922, **41**, 189T).—Smokes, fumes, and dusty gases could all be regarded as disperse systems in which the dispersed substance was solid or liquid and the dispersion

medium a gas. According to the sizes of particles, varying treatments were suggested for dealing with dust and fume. The separation of gas particles by settling was facilitated by retarding the rate at which the gas was travelling, by shortening the vertical path that had to be traversed by the particles, by centrifugal action, by loading the particles with water, by contact with solid surfaces, and by flocculation. Filtration was sometimes employed, either by a tower of coke or more often by " bag-filters " made of cotton, wool, or asbestos. Smoke washing was effected by bubbling the smoke through water, by spraying water into the smoke, or by passing the smoke upwards through an absorption tower packed with coke, gravel, slag wool, coarse sand, asbestos, etc., or down which water was dropping. Electrostatic precipitation was possible with either alternating or direct current.

Various types of apparatus, employing the foregoing methods, were described, the mathematics of settling discussed, and a bibliography was given.   F. W. H.

86. Some Materials of Low Thermal Conductivity. EZER GRIFFITHS (*Trans. Faraday Soc.*, 1922, xviii, Part ii, 252).—The experiments recorded constituted a part of the programme of work for the Engineering Committee of the Food Investigation Board.

The heat insulators in common use were slab and granulated cork, slag wool, and charcoal. A modern refrigerating ship of 6400 tons required about 400 tons of cork. The thermal conductivity of insulating materials was not an invariable physical constant, so that different consignments gave slightly different values. The paper suggested a number of new materials which could be used for cold storage insulation, namely :

(1) *Expanded rubber*. Methods had been devised for the conversion of rubber into a highly cellular form of density 0·059 to 0·12 C.G.S. units (according to method of manufacture). The conductivity of a packing made of clippings of expanded rubber—density 2·6 lb. per cubic foot at a mean temperature of 35°—was 0·000118 C.G.S. unit or 0·342 B.T.U. per sq. ft. per hour for 1 inch thickness and for 1° F. difference in temperature.

(2) *Balsa wood*, from a large tropical tree growing in Ecuador. It was probably the lightest wood known, varying from about 5·7 to 8·6 lb. per cubic foot. The conductivity at a mean temperature of 40° was 0·000122 C.G.S. unit.

(3) *Fibres of wood* Kingia Australis. *Kingia Australis* was a plant peculiar to West Australia, and the fibres were a waste product. With a density of packing 8·4 lb. per cubic foot and a mean temperature 24°, the conductivity was 0·000117 C.G.S. unit.

(4) *Eel-grass mats*. This material was made up of cured eelgrass sewn in between sheets of strong brown paper. With a density of packing 9·4 lb. per cub. ft. and a mean temperature of 30° the conductivity measured 0·000108 C.G.S. unit.

(5) *Compressed peat*. Peat, variously treated, was being extensively used on the Continent for heat insulation. With a specimen of weight 20 lb. per cub. ft. and a mean temperature of 37° the conductivity measured 0·000176 C.G.S. unit.   A. M. J.

VIII.—Chemical Analysis.

87. The Rapid Determination of Potash in Acid-insoluble Silicates. M. M. GREEN (*J. Ind. Eng. Chem.*, 1923, **15**, 163).— The method, based on the assumption that all metals except potassium formed perchlorates soluble in alcohol, was as follows : 0·15 to 0·35 gm. of the sample was weighed into a platinum crucible, 1·5 c.c. of $2N$-perchloric acid, and 3 to 4 c.c. of 48 per cent. hydrofluóric acid were added and evaporated until fumes of perchloric acid were obtained. The mass was cooled, the crucible two-thirds filled with water, heated to boiling, then the contents were filtered and washed thoroughly with hot water. The filtrate and washings were caught in a platinum dish, evaporated until fuming, cooled, and then 25 c.c. of 97 per cent. alcohol added. The residue was well broken up, filtered in an untared Gooch crucible (which had previously been washed with a 1 per cent. solution of perchloric acid in 97 per cent. alcohol), and washed well with perchloric acid– alcohol. (This residue must be broken up well, and be fine and crystalline before filtering, or the subsequent treatment must be repeated.) The asbestos mat was transferred to a filter. The Gooch crucible was washed with hot water, and the washings were poured on to the mat in the filter and the mat and filter washed thoroughly with hot water. By means of this washing, the bulk of the iron and aluminium salts appeared to be decomposed, leaving them as insoluble basic salts on the filter-paper. Hence, omission of this washing and subsequent evaporation led to results considerably high.

The filtrate and washings were evaporated to fuming in a platinum dish with 0·5 to 1·0 c.c. of $2N$-perchloric acid. After cooling, 25 c.c. of 97 per cent. alcohol were added, the residue was broken up, and filtered on to a tared Gooch moistened with perchloric acid–alcohol. After washing well with perchloric acid–alcohol wash-water, the potassium perchlorate was dried at 110° to constant weight. (If, previous to this, the residue was not crystalline, the perchlorate was redissolved, and the evaporation with perchloric acid repeated, when the final weights checked within 0·0003 gm.)

To correct for sulphate, the precipitate was dissolved in hot water, and a drop of barium chloride solution added. Any appreciable precipitate was filtered off, and the filtrate evaporated down again with perchloric acid.

The method was regarded as accurate as required for commercial work, and shortened the potassium determination considerably, but further investigation was advised before using the procedure in work requiring an accuracy of more than $\pm 0·2$ per cent.   V. D.

88. The Volumetric and Gravimetric Determination of Zinc. S. URBASCH (*Chem. Zeitung*, 1922, **46**, 97, 101, 125, 133, 138).—The volumetric method described was for an ore. The

method of decomposition was described and the zinc was obtained as chloride in neutral solution.   At a certain concentration, ferric chloride of known strength was added and the solution titrated hot with potassium ferrocyanide until the blue colour changed to white.   Then the solution was titrated back to pale blue with standard zinc solution.

Experiments with gravimetric methods (excluding determination as phosphate) showed that it was possible to precipitate zinc quantitatively as sulphide from a neutral solution containing up to 3·1 gm. of zinc chloride or 7·5 gm. of zinc sulphate.   The precipitation of sulphide was quantitative, and the precipitate easy to filter, when the solution contained 1 c.c. of normal hydrochloric acid per 100 c.c. and from 0·15 to 0·2 gm. of zinc.   The retarding action of ammonium salts could be overcome by saturating the solution with sulphuretted hydrogen in the cold and then heating in a stoppered flask to 40°.   Formic acid was used in the presence of aluminium, which also tended to hinder the precipitation of the zinc.   F. W. H.

89. The Adsorption of Iron by Precipitated Manganese Peroxide.   M. GELOSO (*Compt. rend.*, 1922, **174**, 1629).—In order to determine the amounts of iron contained in manganese oxides precipitated from acid solutions by means of ammonium persulphate, separation was achieved by use of " cupferron."

From the results obtained it was evident that divalent manganese was displaced by iron adsorbed, and that small concentrations of iron displaced relatively larger amounts of manganese than the higher concentrations.

Increasing the acidity of the solution led to a distinct decrease in the amount of iron adsorbed, but the variation could not be expressed in linear form.   Increase in the concentration of the adsorbent produced considerable increase in the iron carried down, but again the relation was not linear.   The presence of varying quantities of ammonium sulphate had no appreciable effect on the adsorption.   Thus, the adsorption of iron was intimately related to the extent of hydrolysis of the iron salt.   Increased dilution and decreased acidity led to increased hydrolysis, and greater adsorption, whilst substances such as ammonium sulphate which had little or no influence on the hydrolysis had no effect on the adsorption.   The iron which was adsorbed was present, for the most part as hydroxide, not sulphate, and the amount of sulphate remaining depended on the number of washings.   A similar result was obtained on the examination of a manganese precipitate entirely free from iron.   Washing hydrolysed the sulphate.   V. D.

IX.—Machinery for the Working of Glass.

90. Improvements in Hand-operated Bottle Machines.
J. Middleton, 202, High Street, Borough, B. Wilson, 22, Dysons
Road, Edmonton, and Glassworks, Ltd., Kimberley Road,
Edmonton, all in London (Brit. Pat., June 14th, 1921, No. **182664**).
—Relates to glass-bottle making machines of the stationary type
in which turnover heads are employed and manually operated,
and consists in gearing the turn-over heads together in such a
manner that the rotation of one head also turns the other, and
the weights of the heads and moulds are balanced. Arrangements
for cooling the moulds are described. In the construction shown
in Fig. 22 two heads are arranged side by side on a frame, 4, and
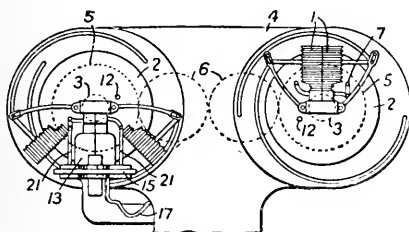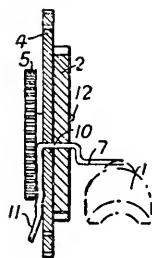
FIG. 22.   FIG. 23.

the turn-overs, 3, of the rotary carrier plates, 2, are geared together
by means of gear-wheels, 5, 6, or by chains. The gearing is so
arranged that when one head is turned over to bring the parison
to the finishing mould, the other head and its parison mould, 1,
is inverted to receive a new charge of metal. Pipes, 7, secured to
the carrier plates, 2, are arranged to direct a current of air down-
wards inside the parison moulds when they are opened. The
pipes, 7, receive their air supply from a pipe, 11, Fig. 23, by way
of a passage, 10, through the plate, 2, the passage being closed by
a spring plug, 12, when the moulds, 1, are inverted to receive metal.
Air is continuously blown on the outside of the finishing-moulds,
13, Fig. 22, from vertical perforated pipes, 21, secured to the mould
carriers, 15. The pipes, 21, communicate with air supply-pipes,
17, by way of ports formed in the mould-carriers.

H. G. C.

91. An Automatic Glass-forming Machine. H. A. Genest,
Hartford, Connecticut, Assignor to the Hartford-Fairmont Co.,
Canajoharie, New York, U.S.A. (Brit. Pat., July 25th, 1922, No.
184172. Convention date August 8th, 1921. Not yet accepted).—
An automatic glass shaping machine, of the type in which the
moulds are carried by a turret rotating intermittingly, has the
moulds arranged in pairs, each pair comprising a parison mould
and a blow mould, adapted to turn about a common axis so

as to invert the moulds and reverse their positions. The operation
of the machine is shown in Figs. 24 to 34. A parison mould, 26,
and a blow mould, 30, are arranged in one head with their
necks pointing in opposite directions. At the first station, a
charge of metal, 27, is fed into the upturned parison mould
and is caused to settle into the ring mould, 28, around the
plunger, 29, by air admitted from a blowhead, 32. The moulds
are then inverted, as shown in Figs. 28 and 29, and after a plate,
33, has closed the bottom of the parison mould, the parison is
blown, by a blowhead, 34, to fill the mould. The ring mould
now opens, transfer tongs, 35, Figs. 30 and 31, grip the mouth of
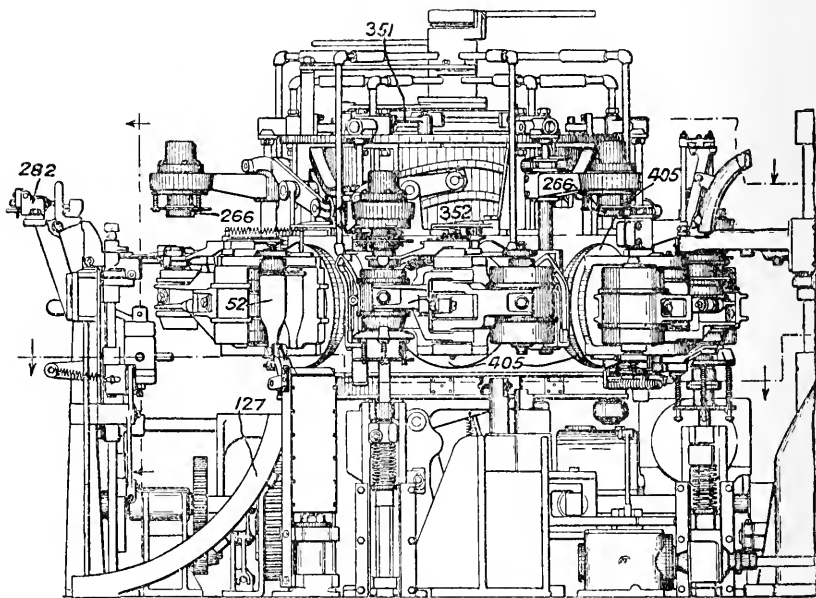
Fig. 24.

the bottle, and the moulds open, reverse, and then close again
so that a finished bottle, 31, is discharged from the blow mould
and is replaced by the succeeding parison, as shown in Fig. 34.
The bottle is now blown to its final form by air from the blow-
head, 34. The moulds radiate from a turret, 40, Figs. 25 and 32,
which rotates about a column, 41, and each pair of mould bodies
is crossed and pivoted at their intersection on a stud, 55.
Provision is made for adjusting the moulds so that the halves are
in proper contact when the bodies are closed. The moulds are
opened and closed by a piston, 66, working in a pneumatic cylinder,
58, which forms the axis about which the moulds rotate, and they
are turned about this axis for reversal by a fixed toothed rack and
by an oscillating toothed rack, 132, which engages at the proper
times a bevel-gear, 130, secured to the mould carriers. The ring

moulds, 28, associated with each parison mould, are carried by
arms, 73, pivoted in the studs, 55, and are opened by links, 80,
operated by cams, 86, carried by a cylinder, 87, fixed on the column,
41. The transfer tongs, 35, which hold the parison while the moulds
are opened and inverted, comprise jaws, 92, Fig. 32, which are

FIG. 25.
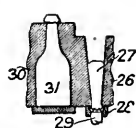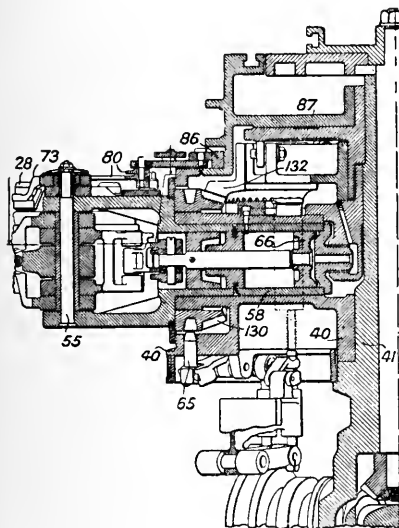
FIG. 26.
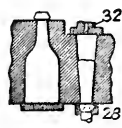
FIG. 27.
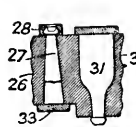
FIG. 28.
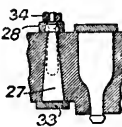
FIG. 29.
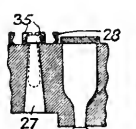
FIG. 30.
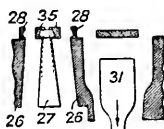
FIG. 31.
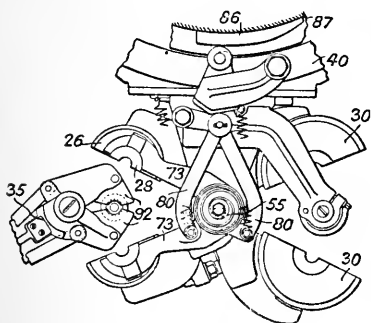
FIG. 32.
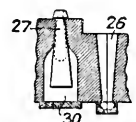
FIG. 33.
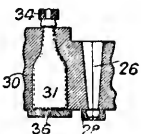
FIG. 34.

lowered into the path of the parison and are opened and closed by
cams. The jaws have a floating movement to accommodate
themselves to slight variations in the positions of the parisons,
and they are arranged to yield if the parison moulds fail to open.
Pins, 65, Fig. 25, reciprocated by cams, lock the mould carrier in
either of the inverted positions.   H. G. C.

92. An Automatic Glass Bottle–making Machine. E. H.
LORENZ, West Hartford, Connecticut, Assignor to the HART-
FORD-FAIRMONT Co., Canajoharie, New York, U.S.A. (Brit.
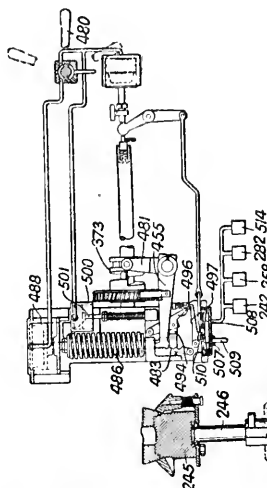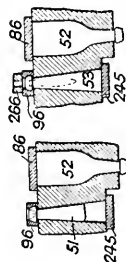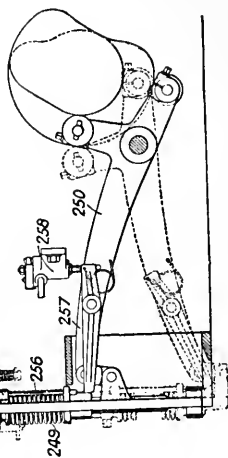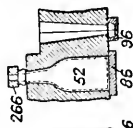
FIG. 43.
FIG. 44.
FIG. 38.
FIG. 42.
FIG. 37.
FIG. 41.
FIG. 36.
FIG. 40.
FIG. 35.
FIG. 39.
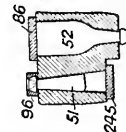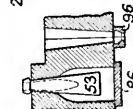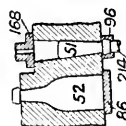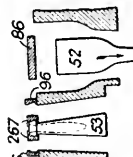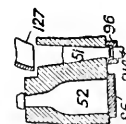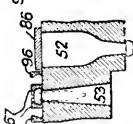
Pat., July 25th, 1922, No. **184171**. Convention date, August
8th, 1921. Not yet accepted).—An automatic machine for
forming glassware adapted to be operated in conjunction with
an automatic feeding-device, is driven mechanically instead of
by compressed air, and is provided with stop mechanism and

safety devices to interrupt the operation of the machine auto-
matically in the event of any irregularity in or obstruction of
the operation of any part of the machine. The machine is pro-
vided with a series of pairs of moulds, each pair comprising a
parison mould and a blow mould arranged side by side on a rotat-
able head with their neck portions extending in opposite directions,
as shown in Figs. 35 to 42. The head is mounted so as to rotate
on a horizontal axis extending radially from a turret which is
rotated intermittingly about a vertical column to present the
pairs of moulds successively to a series of operating stations where
the various steps in the shaping of the ware, indicated in Figs. 35
to 42, are performed. At the first station, a charge of metal, 51,
Fig. 35, from a feeder is guided into the inverted parison mould
by a deflector, 127, Fig. 35, and a blowhead, 168, moves over the
mould and admits air to adjust the metal into the ring mould, 96,
and around the plunger, 214, to form the mouth of the bottle.
The turret next moves this pair of moulds to the next station,
shown in Figs. 36 and 37, and during the movement the moulds
are inverted by the engagement of a bevel gear attached
to the moulds with a fixed sector gear. A bottom plate, 245,
closes the bottom of the parison mould, a blowhead, 266, moves
in contact with the ring mould, and air is admitted to expand
the charge and complete the parison, 53. The moulds are moved
to the next station where the projecting neck of the parison is
engaged by transfer tongs, 267, Figs. 39 and 40. Both moulds are
opened releasing the previously finished bottle from the blow
mould and leaving the parison suspended from the tongs, 267.
The moulds are again inverted by means of an oscillating sector
gear, thus bringing the open halves of the parison mould about
the suspended parison, as shown in Fig. 41. The blowhead, 266,
Figs. 38 and 42, which travels with the moulds, descends in the
neck of the bottle and admits air to complete the blowing operation.
The point at which the blowing commences and its duration
are controlled by tripping devices, mounted on a stationary
drum. The position of these devices may be adjusted to
allow a sufficient time for the parison to elongate and its chilled
skin to be reheated before blowing and give some control over the
setting of the bottle in its final form, the adjustment allowing
these periods to be suited to the different sizes and types of ware.
The turret is given a step-by-step motion by a helix cam, the
drum of which is connected to its driving-shaft by a single-tooth
clutch, 373, operated by a bell-crank lever, 455, 481. The
arm, 455, is moved outwards to close the clutch by means of a
piston-rod, 501, of a pneumatic cylinder, 500, the air supply of
which is controlled by a handle, 480. The arm, 455, is drawn
inwards to open the clutch by a head, 483, on a rod which is moved
by a heavy spring, 486. Before the clutch can be closed, the
handle, 480, is turned to admit compressed air to a cylinder, 488,
which compresses the spring, 486, and moves the head outwards.
A toggle, 494, attached to the head draws a finger, 496, into engage-
ment with a latch, 497, so that the clutch can only remain closed

so long as the finger, 497, is engaged by the latch.   This engagement is ensured by a button, 510, attached to a diaphragm, 508, forming one side of a chamber, 507, to which compressed air is admitted by a pipe, 509.   The chamber is also connected to safety valves, 242, 258, 282, 514, which are associated with different parts of the machine.   Should any of these values be operated through interruption of the associated parts, the pressure in the chamber, 507, falls and the diaphragm, 508, draws the button, 510, inwards.   The pressure of the spring, 486, then causes the latch, 497, to release the finger, 496, and the head, 483, moves the arm, 455, and opens the clutch.   One of the safety valves, 258, is shown in Fig. 44 associated with the mechanism for raising the bottom plate, 245.   The plate is raised by an arm, 250, acting through a spring, 249, on the plunger rod, 246, of the plate to give a yielding pressure.   In the event of the movement of the plate, 245, being obstructed, the spring is compressed and a rod, 256, moves a lever, 257, that is pivoted on the arm, 250.   This movement of the lever, 257, opens the valve, 258, to release the air from the diaphragm chamber, 507, Fig. 43, and allows the spring, 486, to open the clutch, 373.   Overload releases are fixed on the driving shafts which similarly operate the clutch whenever any part of the machine encounters abnormal resistance.   H. G. C.

93. Glass Discharging Device.   S. L. SEARS, Lyndhurst, New Jersey.   Assignor to UNITED BOTTLE MACHINERY Co., New York (U.S.A. Pat., June 8th, 1920, No. **1343183**.   Filed, August 19th, 1914, No. **857463**).—Molten glass is allowed to flow from a tank furnace to an extension in which it may be heated to any desired extent by gas burners.   Inside the extension are a sleeve and a plunger, fitting into a tapered outlet orifice, and sealing it when in the closed position.   When it is desired to withdraw a charge of glass the plug is raised by means of a lever operated mechanically or by hand, and at the same time the sheath is raised, thus permitting hot burnt gases to escape in the form of a cylindrical sheath surrounding the descending glass.   The flow of glass is stopped by reversing the motion of the lever, thus bringing the tapered end of the plug on to its seating.   It is claimed that the glass does not come into contact with any cold part of the apparatus or cold air from the time it leaves the melting furnace until it reaches the mould.   S. E.

94. Blowpipe Operating Mechanism for Glass-forming Apparatus.   A. KADOW, Toledo, Ohio.   Assignor to WESTLAKE MACHINE Co., Toledo, Ohio (U.S.A. Pat., February 24th, 1920, No. **1331772**.   Filed, June 4th, 1917, No. **172704**).—This blowpipe mechanism is designed specially for the Westlake bulb machine, and has for its chief object the spinning of the glass while being blown in the mould at a higher speed than it has during the preliminary forming processes, thus allowing a higher pressure to be used for the blowing air with a consequent improvement in the quality of the bulb.   The blowpipe receives a charge of glass

while in the inverted position as shown on the right hand side of
Fig. 45. Soon after this a low speed gear, 53, is brought into
mesh with a fixed rack, 63, and the blowpipe is rotated on its
longitudinal axis. At about the same time, the blowpipe is turned
from its vertical position by means of the cam, 40, and its associated
mechanism, to the position shown in the centre of Fig. 45. The
rotation of the blowpipe on its own axis continues in this position
until a roller, 74, rides over a cam, 69, which disengages the low
speed gear. During the period that this roller rides along the
cam, 69, the blank is elongated by oscillatory movements of the
blowpipe (see this Journal, ABS., 1921, 5, No. 152). When the roller
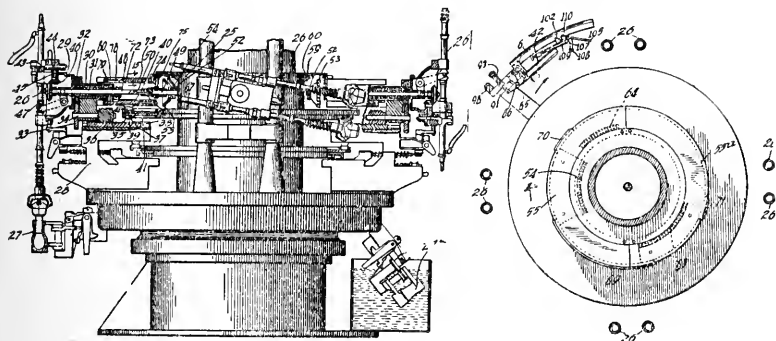
FIG. 45.

runs from the end of the cam, 69, the high speed gear, 52, is brought
into mesh with the rack, 54, by which time the blank has
been enclosed in the mould as shown on the left-hand side of Fig. 45.
Both low and high speed gears operate through the shaft, 48, and
the gear wheels, 43, 44, 46, and 47. After the bulb has been com-
pletely blown, and the mould removed, the neck of the blank
on further rotation is brought against a knife, 42, but before
this actually occurs, a roller, 74, meets a cam, 70, and disengages
the high speed gear, 52, from the rack, 54. As the roller rides
down from the cam, 70, the low speed gear, 53, is brought into
mesh with the reversing rack, 64, causing the neck of the blank
to revolve against the motion across the face of the knife, 42, thus
scoring all round the neck. As the blank moves further round, it
depresses the arm, 108, against the action of the spring, 109, and
carries with it the wood paddle, 105. When the blank has passed
completely over the roller, 108, the arm, 107, is immediately re-
tracted by the spring, 109, and the paddle, 105, is caused to strike
the bulb with sufficient force to crack it off round the neck, without
danger of breaking it otherwise.   S. E.

95. Initial Puff Mechanism for Glass-blowing Machines.
J. WEISENBERGER, Corning, New York. Assignor to Corning
Glass Works, Corning, New York (U.S.A. Pat., March 28th, 1922,
No. **1410857**. Filed, March 14th, 1921, No. **452101**).—This

mechanism is designed to work on an Empire machine, and to cause a puff of air to be blown into the blank before it leaves the marverer.

At the completion of the marvering operation a stud, 5 (Fig. 46), on the face of the cam disc, 7, engages a roller, 35, on the outer end of an arm, 33, secured to the shaft, 32, thus causing the arm, 33, to rise and rock the shaft, 32. The arm on the inner end of

Fig. 46.

this shaft, 32, carries a roller, 28, which rotates the rod, 24, thus causing the finger, 23, on the end of this rod to be withdrawn from its engagement with the head, 22, of the piston rod, 19. Since this piston is normally held at its outward position, on being released, it is moved under the action of the spring, 21, forward in the cylinder, thus giving a puff of air prior to the commencement of the swinging movement of the blowpipe. This puff is only momentary, taking place during the time that the roller, 35, is passing over the stud, 5.   S. E.

96. Method and Apparatus for Marvering Glass.   D. E. GRAY and F. E. BORDROF, Corning, New York. Assignors to CORNING GLASS WORKS, Corning, New York (U.S.A. Pat., March 28th, 1922, No. **1410803**.   Filed, October 20th, 1920, No. **419440**). —In this device the marverer consists of a roller, mounted on bearings and revolved by the driving action of the glass in contact with it.   The marvering roller is also capable of movement towards the axis of the glass under the action of spring pressure.   The surface of the roller is of conoidal form with its apex, when marvering is complete, on the line through the axis of the glass so that the finished blank is slightly conical.

When this method of marvering is used in connection with an Empire machine, the blowpipe, 61, Fig. 47, with a gathering of glass, is inserted in the machine and the cam disc, 5, is set in motion, thus causing a slight raising of the gathering end of the blow pipe.   In this raised position the marvering roller, 39, is brought up into contact with the glass, and held there under the action of a spring, which causes the glass to be rolled out progressively as shown.

On the completion of the marvering, cams on the shaft, 22,
remove the roller from the glass, and allow the blowpipe to swing

FIG. 47.

vertically. During this swinging movement the marvering roller is
lifted clear of the mould by the action of cam tracts, 58, and 59
as shown by the dotted lines.   S. E.

97. Method of and Apparatus for Finishing Bulbs. W. R.
BURROWS, Newark, New Jersey, U.S.A. Assignor to GENERAL
ELECTRIC COMPANY, New York (U.S.A. Pat., January 24th, 1922,
No. **1404268**. Filed, March 31st, 1919, No. **286593**).—In order
to avoid the loss due to breakage in heating up electric lamp bulbs
necessary for cracking off the nearly closed end, freshly-blown
bulbs, without a cracking ring or bead, are taken while still hot
from the mould and suspended, neck downwards, in a travelling
head, which carries them to a cutting off position. Here flames
heat a narrow ring round the neck, and fingers, seizing the neck
below the heated zones, exert a pull sufficient to pull off the waste
part. The bulb, still very hot, is carried to the next position,
where the neck is further heated and reamed outwards, if necessary,
until the bore is of the proper size and the plastic edge is smooth.
When this is completed the bulb is allowed to cool down for the
first time, and is ready for making into a complete lamp.
                                                                S. E.

98. Screw Neck-forming Machine for Glass Vials. H. N.
HALVERSEN, Vineland, New Jersey. Assignor to KIMBLE GLASS
Co., Chicago, Illinois, U.S.A. (U.S.A. Pat., No. **1437239**, November
28th, 1922. Filed December 13th, 1919).—Partly-formed glass
vials, 11 (Fig. 48), are carried in notches, 17, in the periphery of

two discs, 15 and 16, which are intermittently rotated about the shaft, 21. When the vials reach their uppermost position, they are carried on to anti-friction rollers, 18, and are caused to rotate by the action of one or more bevelled rubber rollers, 22, so shaped as to hold the glass vial against the stop, 19. In this position, flames play on the open end of the vial, and when sufficiently heated the neck-forming operation begins. The mechanism for the process includes a plunger, 52, which enters the open end of the vial, by the action of a lever, 56, and a cam groove cut in the face of the
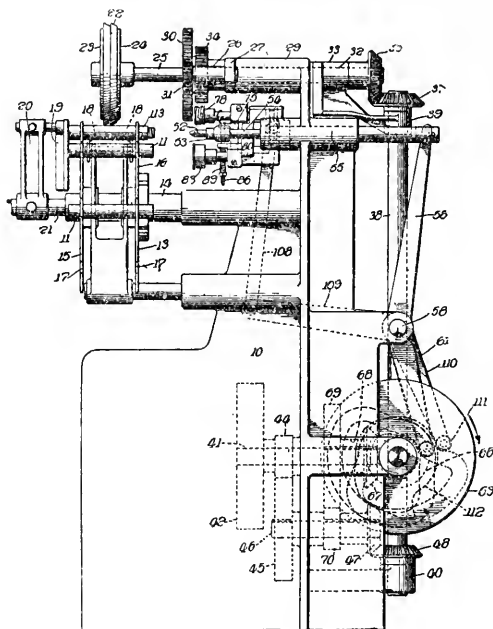
FIG. 48.

disc, 63. A second cam disc controls the motion of the cranked lever, 72, which operates a sliding shaft, 71. Mounted transversely on this shaft is a thread-forming roller, 78, and a corresponding plain roller, 83. These two rollers are brought together by the action of a third cam disc and a rocking arm, thereby forming the reduced threaded neck portion of the vial. The two rollers are then opened and withdrawn along with the central plunger by the action of their several cams, and the conveyor moves one step forward, bringing another blank to the forming position.

<div style="text-align:right">S. E.</div>

99. Improvements in the Mounting of Moulds on Glass Bottle Machines. S. C. HALSE, Albion St., and T. JONES, 27, Nicholson St., both in Castleford, Yorkshire (Brit. Pat., August

23rd, 1921, No. **184699**).—Relates to bottle-making machines in which a divided ring-mould is employed, such as the machine described in Specification 21158/01, and consists in fixing one-half, 1, of the mould to a carrier plate, 3, while the other half, 2, is carried by a member, 8, pivoted to the carrier plate, so that the mould halves can be separated by turning the member, 8, by means of a handle, 10. The section, 2, is normally maintained in the closed position by means of a spring or, preferably, by means
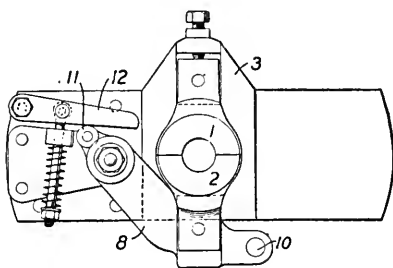
Fig. 49.

of a spring-controlled pivoted arm, 12, which presses against a tail-piece, 11, on the member, 8. With this construction, the section, 2, is held either in the closed or in the open position. In a modification, the tail-piece, 11, is pivoted to a rod which slides through a bracket, a spring surrounding the rod forcing the mould section either into the closed or into the open position.

H. G. C.

100. Alloys for Moulds. R. L. FRINK, 50, Bedford Square, London (Brit. Pat., April 26th, 1921, No. **183582**).—Metal moulds for glass working are made with a porous or finely pitted surface. Such moulds may be made from an alloy of aluminium or copper with calcium, barium, or magnesium, the surface being rendered porous by treating it with an alkaline solution. A suitable alloy contains about 2 per cent. of calcium or barium. In making this, an alloy containing 75 per cent. of aluminium and 25 per cent. of calcium, etc., is first prepared at a temperature of 500° to 1100°, and added in the required proportion to pure molten aluminium. For use the moulds may be dipped in water, paraffin, oil, etc.

H. G. C.

101. Machine for Burning or Glazing the Edges and Sides of Glassware. A. B. KNIGHT, Fairmont, West Virginia, U.S.A. (U.S.A. Pat., January 11th, 1921, No. **1364939**. Filed, August 8th, 1919, No. **316102**).—The chief object of this invention is the simultaneous glazing of the edges and sides of such articles as tumblers. The carriers, 64, (Fig. 50), for holding the ware are mounted on short stout spindles, 56, which are attached to an adjustable frame, 52, the whole of which may be raised or lowered by turning the handle, 24, to suit the size of the ware being glazed. On rotating the machine about its central standard, 60, the arms, 52, being fixed on the gear wheel, 33, are rotated with it, whilst the gear, 62, being secured to the standard, 60, is fixed against rotation. Thus by the medium of the pinion, 57, the spindles, 56, are caused to rotate on their own axis as they are slowly moved forward, and the ware they carry as it enters the fireclay tunnel, 74, is subjected

to the action of a number of flames.   The upper edges are uniformly remelted by the flames issuing from the continuous series of holes, 69, in the wall of the gas chamber, 68.   At the same time,
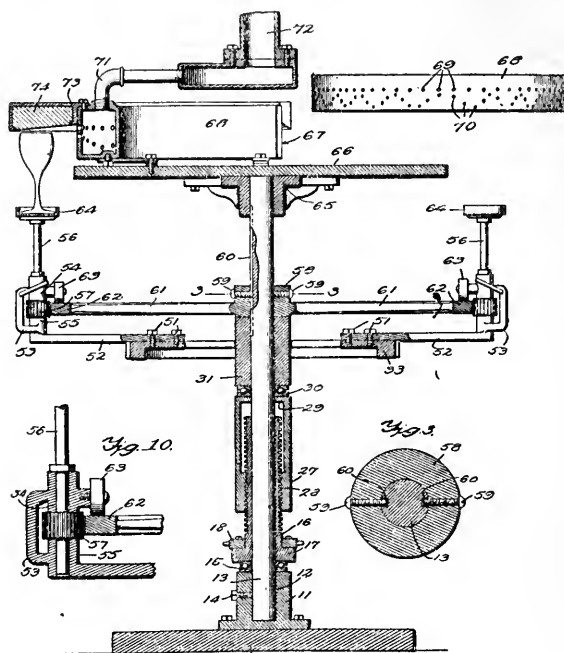
FIG. 50.

the sides of the ware are glazed by flames from the openly spaced and staggered holes, 70, which direct flames to all parts of the outside of the ware.   S. E.

102. Fire Polishing Apparatus. C. A. SUNDER, Jeannette, Pennsylvania.   Assignor to McKEE GLASS Co., Jeannette, Pennsylvania (U.S.A. Pat., June 28th, 1921, No. **1383171**. Filed, September 18th, 1919, No. **324644**).—A glass article such as a bowl, 32 (Fig. 51), is placed on a suitably shaped carrier, 29, in the position outside the furnace chamber, 11. The whole assembly is then pushed along a slide to the position shown in the
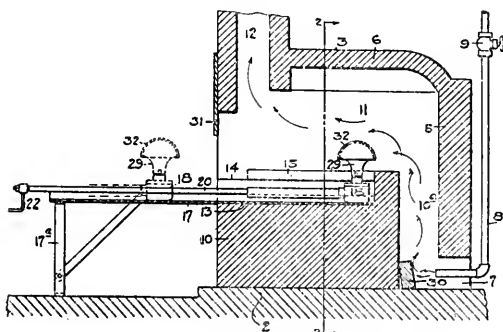
FIG. 51.

furnace, where the glass is subjected to the heat from the burning gas in the passage, 10^a, as the products of combustion pass to the flue, 12. The ware is rotated by means of the handle, 22, which acts through bevel gears in the gear-box, 18. This gear-box and the vulnerable working parts are shielded from the direct heat of the flames by slabs of refractory materials. S. E.

103. Glass Finishing Tool. A. J. SANFORD, Newark, Ohio. Assignor to A. H. HEISEY & Co., Newark, Ohio (U.S.A. Pat., November 28th, 1922, No. **1436825**. Filed, June 17th, 1921, No. **478355**).—This tool is designed to remove the annular thickened ring formed on the upper edge of such articles as tumblers during the fire finishing operation. It consists essentially of two hinged
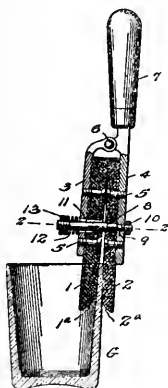
FIG. 52.
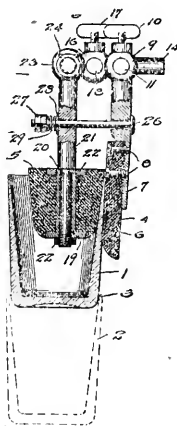
FIG. 53.

fingers, 1, 2 (Fig. 52), preferably made of carbon, and flared outwards at their lower ends. The carbon fingers are secured to metallic plates, 3, 4, which are hinged at 6. The opening between the two fingers is controlled by the tension bolt, 8.

In operation the glass article while hot is rotated, the tool placed over the edge and gradually lowered, thus exerting a straightening effect and eliminating the thickened edge, or any curvature due to remelting the edge. S. E.

104. Glass Finishing Machine. A. H. HEISEY, Newark, Ohio. Assignor to A. H. HEISEY & Co., Newark, Ohio (U.S.A. Pat., November 28th, 1922, No. **1436878**. Filed June 17th, 1921, No. **478356**).—This apparatus is a slight modification of the one described in the previous abstract (No. **103**) and consists in replacing one or both of the hinged fingers by a tapered roller or rollers as shown in Fig. 53. S. E.

105. Rolling Machines for Making Plate Glass. A. W. MATHYS, 52, Chancery Lane, London (Brit. Pat., April 1st, 1921, No. **182551**; Bicheroux, Lambotte et Cie, Herzogenrath, near

Aix-la-Chapelle, Germany).—Relates to a method of producing high-grade plate glass by a double-roll machine, similar generally to the Chance double-roll machine as used for the production of sheet glass. According to the invention, the whole refined contents of a melting-pot are charged in one mass, c, Fig. 54, into a rolling mechanism, the resulting plate being received upon a travelling table, i. In a modification, the glass is teemed upon a receiver, d, Fig. 54, to which the upper roll, f, is connected, and the receiver, d, and roll, f, are then swung up to the position shown by the dotted lines so as to promote the passage of the glass between the rolls. In a further modification, several sets of rolls, f^1, f^2, f^3,
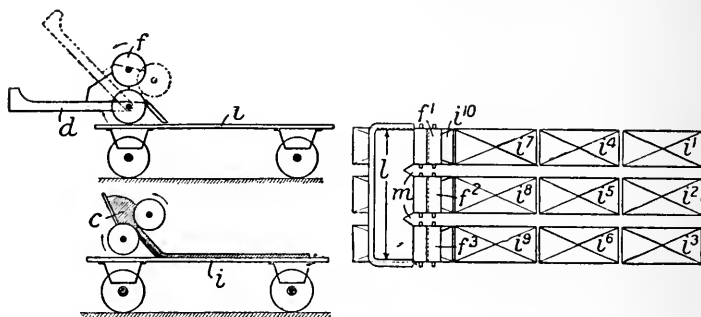
Fig. 54.

are fed from one teeming-plate, l, guides m directing the molten metal on to the rolls. Several receiving-tables, i^1, i^2, etc., may be employed, and the glass plate may be cut into sections while still soft. Specification 13119/84 is referred to.   H. G. C.

106. A Method for Continuously Drawing Sheet Glass. E. ROWART, Auvelais, Belgium (Brit. Pat., July 5th, 1922, No. **182805**. Convention date, July 11th, 1921. Not yet accepted).— In a process of drawing glass in continuous sheets, the width of the sheet is preserved by drawing the edges from metal which issues from channels in refractory blocks, and means are provided for regulating the temperature and consistency of the body of the metal and the temperature of the sheet as it is drawn upwards. The metal flows from a tank, 1, Fig. 55, under a floating bridge, 4, into a forehearth, 2, where the depth of metal is small compared with that in the tank.   The position of the bridge, 4, can be adjusted in order to regulate the condition of the metal in the forehearth. The drawing chamber is formed by an open-ended box or casing, 12, of refractory material which is adjustably supported on walls, 8, extending downwards from the crown of the forehearth, a second chamber, 16, which contains the drawing-apparatus, resting in the casing, 12.   The drawing-chamber proper, 14, is formed by walls, 13, in the interior of the chamber, 12, which are separated at the top and extend downwards to the surface of the metal, thus delimiting an area of metal from which the sheet is drawn.   At the

sides of the chamber, 14, are adjustable shields, 18, Fig. 55, which
control the extent to which the hot gases circulate over the side
portions of the metal and thus assist in regulating the temperature
of the metal in the drawing-area. In front of the shields are
" plungers," 24, consisting of blocks of refractory material which
dip to an adjustable extent in the metal. A " plunger " has a
recess, 27, the lower wall of which is wedge-shaped, and is perfor-
ated with a passage, 25, through which passes the metal from which
the edges of the sheet are formed. In operation a bait is lowered
through the space, 35, at the top of the drawing-chamber, and
after the metal has adhered, is drawn upwards to the chamber, 16,
in the usual manner. The bait has depending portions at its ends
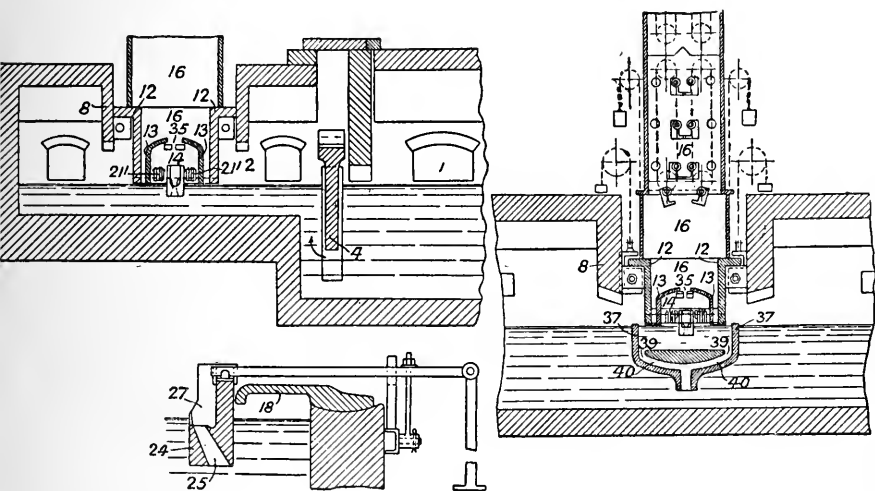
Fig. 55.

which enter the recesses in the " plungers," 24, and draw the metal
from the passages, 25.

The edges of the sheet are thus drawn from separate portions
of metal which unite with the body of the sheet as they leave
the passages, 25. The temperature of the sheet is regulated as
it is drawn upwards by means of metal coolers, 21', contained in
the drawing-chamber, 14, through which water is circulated.
Curtains or shields of refractory material may also be used to control
the radiation from the surface of the sheet. In a modification,
shown in Fig. 55, the metal from which the sheet is drawn is con-
tained in a box-like structure, 37, of refractory material which
dips into the metal and communicates with the body of the tank
through grooves and passages, 39, 40. Metal passes through these
grooves into the interior of the structure, thus obtaining a com-
paratively small volume of metal at the temperature necessary for
drawing.   H. G. C.

107. Improvements in the Method of Drawing Glass Sheets. W. J. MELLERSH-JACKSON, 28, Southampton Buildings, Holborn, London (Brit. Pat., July 28th, 1921, No. **184053**) (Libbey-Owens Sheet Glass Co., Nicholas Building, Toledo, Ohio, U.S.A.).—Relates to sheet-drawing apparatus of the type described in Specification 114977 in which marring of the surface
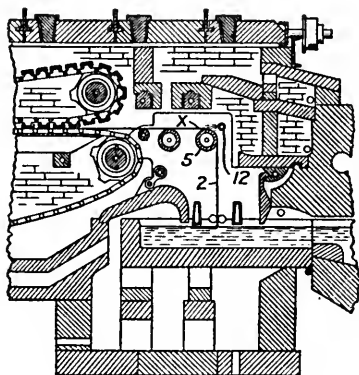
FIG. 56.

of the sheet is prevented by adjusting the temperature between the drawing point and the bending-roll, 5. The invention consists in reheating the sheet, 2, for example, by gas jets, 12, at the point, X, where it leaves the roll so that the drawing tension overcomes the tendency for corrugations to form in the sheet due to bending when cooled. Air may be circulated through the roll, 5, to prevent it from becoming overheated.   H. G. C.

108. Method for Drawing Sheet Glass. W. J. MELLERSH-JACKSON, 28, Southampton Buildings, Holborn, London (Libbey-Owens Sheet Glass Co., Nicholas Building, Toledo, Ohio, U.S.A.)
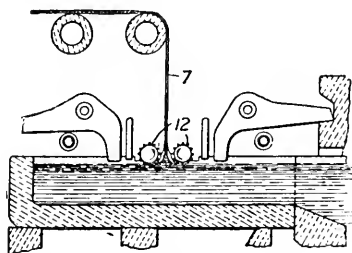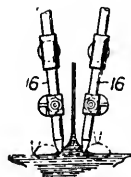
FIG. 57.   FIG. 58.

(Brit. Pat., July 28th, 1921, No. **185921**).—Relates to apparatus of the type described in Specifications 15134/15 and 114977, for drawing glass in flat sheets, and consists in chilling those portions of the surface of the molten metal from which the edge of the

sheet are drawn and simultaneously forcing these chilled portions to flow upwardly into the sheet. In the device shown in sectional elevation in Fig. 57, the metal near the edges of the sheet, partly cooled by proximity to the sides of the tank, is further chilled by contact with teeth or pickers, 12, projecting from water-cooled hubs, which dig into the surface portions of the metal. The rotation of the hubs feeds the chilled metal towards and into the body of the sheet, 7, as it is drawn upwards. In another construction, shown in Fig. 58, two water-cooled pickers, 16, are moved in a vertical plane, their points moving in the paths shown in dotted lines. In a modification, L-shaped pickers are arranged horizontally, and the points follow elliptical paths which dip into the metal at the lower parts of their orbits and carry it inwardly toward the sheet.   H. G. C.

109. Drawing Sheet Glass. W. J. MELLERSH-JACKSON, 28, Southampton Buildings, Holborn, London (Libbey-Owens Sheet Glass Co., Nicholas Building, Toledo, Ohio, U.S.A.) (Brit. Pat., July 28th, 1921, No. **184989**).—Relates to the process of
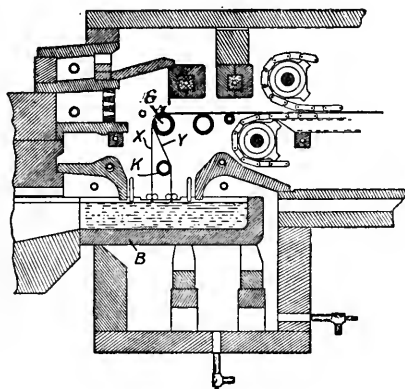
FIG. 59.

drawing glass in flat sheets and consists in protecting the sheet during drawing from injurious contact with the bending-roll and other supports by interposing a second sheet between it and the supports. As shown, two sheets, X, Y, are drawn upwards from the metal in the receptacle, B, and pass around the bending-roll, G, into the lehr. A roll, K, keeps the sheets apart, but they are sufficiently cooled by the time they reach the roll, G, to prevent adhesion. The sheet, X, is thus protected from contact with the rolls by the sheet, Y.   H. G. C.

110. Apparatus for Drawing Glass in a Flat Sheet. W. J. MELLERSH-JACKSON, 28, Southampton Buildings, Holborn, London (Libbey-Owens Sheet Glass Co., Nicholas Building, Toledo, Ohio, U.S.A.) (Brit. Pat., July 28th, 1921, No. **184990**).—Relates to

apparatus for drawing glass in a flat sheet and consists in providing means for forming and maintaining, in the molten glass, cooler areas of viscous glass, as sources from which the edges of the sheet are drawn, in order to prevent the sheet from narrowing as the drawing proceeds.   In the apparatus shown in Fig. 60, water-cooled members are arranged at the sides of the drawing-pot, 6, each member consisting of a horizontal pipe, 8, having a hatchet-shaped end, 10, which dips into the metal, 2, as shown.   The circulation of cold water through the members cools the metal surrounding the ends, 10, and surrounds them with masses of stiff, viscous metal which serves as a source for the edges of the sheet, 1.   The ends, 10, may be covered with refractory material in order to modify the cooling effect and to prevent metallic contamination of the glass.   In a modification, shown in Fig. 60, the cooling-
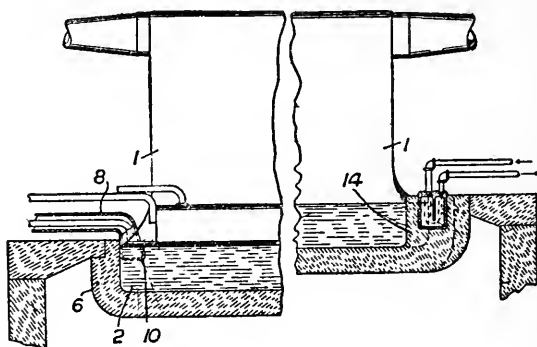
Fig. 60.

devices are buried in the sides of the drawing-pot, **V**-shaped ribs, 14, being formed on the inner sides of the pot in front of the cooling-members.   H. G. C.

X.—Glass Accessories.

XI.—General.

111. Standard Milk Bottles.   A. E. WILLIAMS (*Glass Container*, 1923, **2**, 12).—The U.S. Bureau of Standards had sought to eliminate the non-uniformity of sizes and markings of milk bottles, as at present required by different State laws, by a standardisation of size and markings selected from the best designs.

V. D.

112. The Evolution and Development of Glass House Equipment. J. S. Herzog (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 124).—A general account of the evolution of machinery used in glass-making. In burning gas, a greater efficiency was obtained when the air entirely surrounded the gas stream as it entered the combustion chamber. Oil burning under high pressure was more efficient than under low pressure when the oil was atomised by compressed air. The installation for the use of high-pressure oil was, however, more costly.

A call was made for a better metal or alloy for mould-making.

Although a great many improvements in glassworks equipment had been made, in 1914 the glass industry ranked thirteenth in percentage of labour cost on the value of the product. Government reports for the year 1917 showed labour to account for 40·6 per cent. of the cost of manufacture of glass. F. W. H.

Reviews.

The Fourth Annual Report (for the Year 1921–22) of the British Scientific Instrument Research Association.—The writer of the report in question decided to give, not only an account of the year's working, but to review also the work of the Association during the four years of its existence. This decision was a very wise one and has made it possible to convey a truer view of the accomplishments of the Association.

Most workers who have been thrown into contact with industries have had to face the position that researches alone, such as would appeal to the highly trained scientific worker, may leave that industry perfectly cold by sheer reason of its difficulty in understanding their bearing. Another fact which comes to be realised before very long is that many valuable researches, and even some smaller ones, are actually instigated by practical workshop difficulties. This has been the position of the Research Association in question, and its work accordingly has been divided into three branches, namely, fundamental researches; researches on urgent problems of immediate application, and others to solve technical difficulties arising in individual workshops. The report goes on to give an outline account of the work done under each of these headings.

Under the heading of fundamental researches, four special lines of research are mentioned, namely, abrasives and polishing powders; the durability of optical glasses; the production of new types of optical glasses, neutral glasses and coloured glasses; wave form and X-rays.

The investigations undertaken because of urgent problems of immediate application led to the production and actual manufacture of a special type of rouge for polishing and a special abrasive, both of which have been extensively used in the workshops of the Association. Other researches to meet special needs resulted in the

production of a high melting-point solder, an optical grease, a plastic adhesive wax, and cements for glass metal surfaces.

The work done under the heading of technical difficulties in workshops has been of very varied character.

It is a matter of congratulation that the Association has been carried on on a careful and conservative financial basis. The report states that the Association has kept its expenditure within the limits originally provided for, and that the sum guaranteed by the Department of Scientific and Industrial Research in aid of the Association's work would not be expended at the end of the fifth year; the balance, indeed, is stated to be sufficient to maintain the Association on its existing scale for a sixth year, and thus give full time for securing finances from the industry in order to carry on after 1924 what, in the reviewer's opinion, is both good and necessary work.

W. E. S. T.

A Text–book for Salespeople in the Retail Section of the Pottery and Glass Trades. (SCOTT, GREENWOOD & SON, London, 1923. Price 2s. 6d. net.).—It was a very happy idea of the Pottery and Glass Trades Benevolent Institution to establish in London, a year or two ago, courses of lectures especially directed to the interest and instruction of those engaged in the retail glass and pottery trades. These courses were well attended, and successful students in the examinations which followed were taken for a tour to the workshops of the pottery and glass districts, in order that they might see, first-hand, the processes of producing artistic ware.

The little book before us contains an outline of the production of artistic pottery and glass, and will make it possible for many who were not fortunate enough to be able to attend the lecture courses to obtain the same information. The text-book consists of an introduction, pointing out the advantage to the salesman of a knowledge of the products he has to dispose of; three sections or parts, comprising 32 pages, dealing with historical notes and general information on pottery and pottery in the making; and a fourth part consisting of notes on the history, manufacture, and decoration of flint glass table-ware and ornamental glass. This part occupies about 42 pages. A further section gives information on the composition of sets of china, such as tea-sets, and also of glass drinking services. The book contains 65 figures and illustrations and is very readable.

W. E. S. T.

Directory of the British Glass Industry. Compiled by G. S. DUNCAN, M.A., B.Sc., F.C.I.S., and edited by Professor W. E. S. TURNER, D.Sc. (Published by the SOCIETY OF GLASS TECHNOLOGY, Sheffield, 1923. pp. 384. Price 7s. 6d.).—This volume will prove valuable to all manufacturers and business men whose interests are connected in any way with the glass industry. The information collected and classified is comprehensive, and omissions are few and unimportant.

The Directory is divided up into ten Sections, as follows :—A. Alphabetical List (with particulars) of Glass Manufacturers; Manufacturers of Lamp-worked and Scientific Glass Articles and Optical Apparatus; Glass Manipulators; Craftsmen in Stained Glass, etc. B. Classified Lists (names only) of Firms entered in Section A. C. Wholesale Dealers in Glassware. D. Alphabetical List (with particulars) of Firms supplying materials used in the Glass Industry, machinery, plant, raw materials, etc. E. Classified Lists (names only) of firms entered in Section D. F. Industrial Associations. G. Trade Unions and their Officials. H. City Companies. I. Educational Institutions, Scientific Societies, and Research Associations; and J. Publications.

The section dealing with Publications includes a list of all the Continental and foreign journals dealing wholly or partly with glass, either from the scientific or technical point of view, and gives information as to price, times of publication, and names of publishers. In view of the scarce and scattered nature of the literature connected with the glass industry, this section should prove exceptionally useful.

The Directory, which contains 384 pages (including advertisements), has been carefully compiled, and the information supplied is accurate, interesting, and well arranged. In view of the many ramifications and various needs of different branches of the glass trade, such a work of reference has been greatly needed and the present issue will satisfy a long-felt want.

J. H. D.

Elements of Glass Blowing. By H. P. WARAN. (Pub. by G. Bell & Sons, Ltd., London. ix + 116 Pages, and 39 Figures. 2s. 4d.)—The literature in the English language on glass-blowing (bench glass-working) is very meagre, and therefore the appearance of a new book on the subject is welcomed by all interested in the subject. The present book is written by an amateur worker, largely for the benefit of science students, to whom some acquaintance with this subject is becoming more and more necessary. Although a little tuition by a suitable professional worker is more effective than the study of any book can be, to those students to whom such tuition is inaccessible the present book will be found quite useful.

Turning to detailed criticism, it is to be remarked that, owing to the rather unusual arrangement of the chapters, the making of internal junctions and completely closed circuits—two of the most difficult things a beginner has to learn—are dealt with before the making of test-tubes and thistle funnels, or the blowing of bulbs.

It is rather unfortunate that when dealing with the position of the work-table, etc., the author does not deal with the position that should be adopted by the worker, as the assumption of an unsuitable attitude is unnecessarily tiring and renders the hold on the glass somewhat unsteady and uncertain.

The chapter dealing with glass-blowers' tools would have been

much improved if modern tools and blowpipes had been described. A crude form of Gillingham's double blowpipe is described, but no mention is made of more recent variable jet blowpipes or of burners using pre-heated gas and air; neither are Bornkessel jets mentioned.

In Chapter VI the author goes into details of the process of "spinning" glass, asserting that there is no adequate description of the process; but what he calls "spinning" is dealt with in other books under the names "flanging" or "turning," and details of this process, together with a description of flanging tools, may be found in half a dozen books on this subject.

When dealing with the making of ground joints and taps, it is stated that the two corresponding portions may be ground together without first being ground down by conical lapping tools. Even a professional worker would hesitate to do this, so that a learner or an amateur worker would have great difficulty in obtaining a tight ground joint by these means.

The last chapter, dealing with Commercial Methods of making laboratory glassware, is so very brief, and, unfortunately, contains so many inaccuracies, that it would have been better not attempted. A much more useful chapter could have been added dealing with the defects in glass tube, for example, uneven thickness of wall, blooming, and devitrification, which are not mentioned, although they are very important considerations in determining the suitability or otherwise of tube for lampworking purposes.

S. E.

Glass-making in England. By H. J. POWELL. Cambridge University Press. 1923. x + 183 Pages and 107 Figures. Price 25s. net. The author, whose death we have recently had to deplore, has left us a legacy rich in his own experience and in the records which he has gathered from many sources of the story of English glass-making. The book appears to have been undertaken partly because of the author's view that glass-making as a handicraft is dying out. As he says in the preface, "Few genuine handicrafts remain, and the handicraft of glass-making is doomed, owing to the scarcity of recruits and the development of machinery. The training required to equip a competent glass-blower is long and arduous, and the prospect of ultimate success is not sufficiently bright to attract youths to adopt glass-blowing as their trade." This view that glass-making by hand is doomed may or may not be correct. We trust that a revival may occur before long in the highest branches of the art. In any case, the expression of opinion is not that of the elderly man looking back with regret and sighing for the better times which have gone, for his book closes with the expression of a belief in the artistic possibilities of glass in itself, however worked. He says (p. 173), "If mechanically produced table ware is inartistic and ugly, the fault lies with the designer. . . . It is quite possible, however, to design table ware for mechanical production which shall be gracious in form and which shall possess sufficient decoration to accentuate the beauty of the material."

In the compass of its 183 pages the book contains a mine of information of a most attractive character. Of the fifteen chapters, two, namely, that on Coloured Glass, and Extracts from the Notes of a Flint Glass Works Manager, have already appeared in substance in our own JOURNAL.

The author traces the technique of English glass-blowers back to the glass-blowers of Imperial Rome and to the Roman provinces of Syria, Egypt, and Gaul. He brings together and discusses the earliest trustworthy information about the development of the industry in England, devoting a considerable portion of Chapter II to a discussion of the glass-makers at Chiddingfold, Surrey, of which authentic records go back to 1226, and to the advent of the glass-workers from the Low Countries and from Venice. Chiddingfold, we gather, so little known in England, was, however, known in Italy, and it could scarcely have been on any other ground than that of its manufactures of glass. The wanderings of the Hennezels are traced through Surrey, Sussex, and Hampshire, to Worcestershire, Newcastle, and London, and some records of the family quoted, extracted from parish registers. What is known of Jacob Verzelini is also told, and we have a portrait of himself and wife taken from brasses, and photographs of two of his productions in glass in London, etched with the diamond-point. Mansell's activities are well described, and we learn that his efforts must have been fairly successful in that in 1639 he claims to have brought down the prices of "Cristall beer glasses from Venice from 24s. to 10s. and 11s. per dozen," and "Cristall wine glasses from 18s. to 7s. and 8s. per dozen."

For glass bottle manufacturers, the chapter on Old English Bottles and Flint Glass Decanters is bound to be of interest. It recalls a thirteenth-century instruction for making a bottle : " If you wish to make bottles, this do. When you have gathered some hot glass on the end of a blowing-tube and blown it in the form of a large bladder (quasi vesicam), swing the tube with the glass appended to it beyond your head as if you intended to throw it, and the neck will be stretched by this action ; then separate it with a wet stick and put it in the annealing furnace."

Even from the middle of the seventeenth century, bottle-making appears to have been segregated and " all English wine bottles were made in so-called ' bottle-houses.' " At first, the bottle was little more than a kind of flask, or bulb with a long neck. Between 1680 and 1720 the neck became shorter and more tapered and the " kick-up " wider and higher. By 1750 a cylindrical body had been evolved.

In his chapter on Cut Glass the author points out how little appreciation this craft seems to have met with in this country. Only in Ireland does there appear to have been a real appreciation of its merits in the eighteenth century. Yet even in the middle of that century English glass had acquired fame on the Continent. According to Gerspach, " The English glass which entered into competition with the Bohemian glass, in the middle of the eighteenth century, dealt a deadly blow to Bohemian colourless

glass. The English material lent itself to facet-cutting infinitely better than the Bohemian, and beat the Bohemian glass, as that had beaten Venetian glass. It became the rage in all the continental cities and eclipsed the Bohemian cut glass." The chief centres of glass-cutting in the eighteenth century were Birmingham, Bristol, London, Stourbridge, Whittington near Chesterfield, and Waterford. The industry at this last-named centre in Ireland was not native, but was started by a complete staff of glass-workers drawn from Stourbridge.

Space does not permit to refer to any more of the interesting contents of the book, and it must suffice to add that there are other chapters to which no reference has been made in the above review dealing with : English Drinking Glasses ; Old London Glass-Houses ; Provincial Glass-Houses ; Cast Plate-Glass ; Flint Glass ; The Excise Period ; The International Exhibitions of 1851 and 1862, and Glass-making during the War. The book contains 106 illustrations, most of them photographic reproductions, and a map showing the position of old London Glass-houses at about the middle of the eighteenth century. The get-up of the book is attractive. We have found, during a first examination, no errors, and we are quite confident that the book will have a wide appeal in this country and America, not only to collectors of glass, but also to glass manufacturers.   W. E. S. T.

I.—Glass-making Materials.

113. Burnt Lime or Limestone (in Glass–making). IRVING E. ADAMS (*Glass Industry*, 1923, **4**, 6).—In the manufacture of polished plate glass, limestone was used, and tests did not seem to indicate that by substituting burnt lime any increase was gained in the speed of production; other tests with a straight soda-ash–burnt lime-charge showed by their want of success that it was wise to use 60 to 70 lb. of salt-cake per batch of 1000 lb. of sand. In the window-glass industry, limestone was used because of its low cost, the fusibility of limestone–salt-cake mixtures, and the large melting areas involved. In both industries, a high lime content was preferred, especially in machine-operated plants.

In the production of flint glass bottles and blown and pressed ware, and in some cases with green bottles, burnt lime was used; green glass fruit jars and tank-made amber glass were made mostly from limestone.

Burnt lime appears to have been given precedence in general when a decolorising agent was employed, quality being more important than cost. Most users of burnt lime appeared to favour the high magnesia or dolomitic variety, possibly due to the constancy of the product from the Ohio region.

The following table was given, showing the weights of burnt lime or limestone used per 1000 lb. of sand :

Ware.	Burnt lime.	Limestone.
Milk bottles	120 lb.	—
Flint bottles in general	110	—
Pressed tumblers	100	—
Blown tumblers	95	—
Lamps, chimneys, vases	90	—
Large blown objects	75	—
Fruit jars	—	180 lb.
Green bottles	110	200
Polished plate	—	330
Window glass	—	360

In a works test, a coarsely-crushed magnesium limestone was worked under the same conditions as burnt lime from the same deposit. The limestone batch, however, gave continually a seedy glass, and uniformity of colour was difficult to maintain.

It was pointed out that the degree of fineness of the limestone made an important difference to the speed of melting in a polished plate factory; but in a factory making large blown objects, the change from very finely divided (and very pure) limestone to burnt lime in the batch gave no discernible increase in the rapidity of melting. The latter point was corroborated at a green glass bottle factory where a finely pulverised limestone (1 per cent. iron oxide) was changed over to burnt lime to improve the colour; the required

change was effected, but the production of plain glass melted was not increased.

There seemed to be no noticeable trend away from the use of burnt lime where its use had become standard practice.

W. C. S.

114. Lime as a Glass-melting Material. L. SPRINGER (*Sprechsaal*, 1923, **56**, 188).—Instances were furnished which demonstrated the need of the chemical control of samples of lime used in glass works. The degree of fineness of the particles was also important, as also the mineralogical composition. A small experiment in a platinum crucible heated in an electric crucible furnace showed that a sample of shell-limestone liberated all its volatile material far more readily than did marble. In another case, the development of " stones " followed the use of a new lime; the latter was found to have more insoluble matter and less calcium carbonate per cent. Again, another firm had used a local and cheaper marble than their previous limespar. The new melt was not successfully worked, and more alkali had to be used, so that the original economy was ineffective, due to mineralogical differences in the samples.   W. S.

115. Occurrence, Chemistry, and Uses of Selenium and Tellurium. V. LENHER (*Transactions American Institute of Mining and Metallurgy*, Paper No. **1198–N** (advance copy), January, 1923).—Following a brief description of the sources of the two elements, qualitative and quantitative tests for them were described. Selenium compounds heated in the reducing flame gave fumes with a horseradish odour; in the oxidising flame, a characteristic blue colour was obtained. Tellurium gave white fumes with no characteristic odour, whilst in the bunsen flame tellurium compounds gave a pale bluish-green flame. In both cases, the element gave a white, volatile oxide when roasted in air.

Concentrated, or fuming, sulphuric acid dissolved both elements, producing green solutions of $SeSO_3$ or red $TeSO_3$. When these solutions were poured into water, the elements were precipitated. On warming the above concentrated acid solutions, sulphur dioxide was evolved and soluble selenium dioxide or insoluble basic tellurium sulphate was obtained. Sulphur dioxide when passed into a hydrochloric acid solution of selenium precipitated the element, whilst sulphuretted hydrogen with selenious acid precipitated yellow selenium sulphide, which was rapidly dissociated. Selenium was obtained by reduction from selenates or selenites by potassium iodide, from selenites by stannous chloride, ferrous sulphate, hydroxylamine hydrochloride, phosphorous acid, or hypophosphorous acid. Tellurium was precipitated from solution by stannous chloride, hypophosphorous acid, hydrazine hydrochloride, or metals such as zinc, aluminium, or magnesium. Barium selenite and tellurite were insoluble in neutral solutions, but soluble in hydrochloric acid. Barium and other selenates and tellurates were reduced by boiling hydrochloric acid to selenites and tellurites.

Amongst quantitative methods of estimation, the simplest was the process of reduction of the selenites by sulphur dioxide or hydroxylamine hydrochloride, or of the tellurites by sulphur dioxide or hydrazine hydrochloride, with subsequent filtration of the element in a Gooch crucible. Selenates needed first reducing to selenites by boiling with hydrochloric acid, but Lenher and Hamburger had shown that tellurates could be decomposed by a mixture of sulphur dioxide and hydrazine in 10 per cent. hydrochloric acid. Selenium, precipitated by potassium iodide in hydrochloric acid solution, could be filtered in a Gooch crucible and weighed after boiling off the iodine.

Norris and Fay treated a hydrochloric acid solution of selenious acid with excess of standard sodium thiosulphate, and titrated the excess of this with iodine. The reaction was :

$$H_2SeO_3 + 4Na_2S_2O_3 + 4HCl = 4NaCl + Na_2S_4SeO_6 + Na_2S_4O_6 + 3H_2O.$$
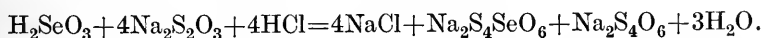
Selenates or tellurates could be estimated volumetrically by boiling with hydrochloric acid and absorbing the evolved chlorine in potassium iodide. Gooch and Reynolds boiled selenates with hydrochloric acid and potassium iodide, obtaining the following quantitative reaction :

$$H_2SeO_4 + 6HI = Se + 3I_2 + 4H_2O.$$
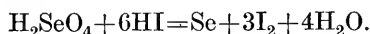
The iodine was collected and titrated. A further volumetric method for selenites and tellurites consisted in oxidising these to selenates and tellurates with standard permanganate. The fading of the end-point was avoided by adding excess of this reagent, running in excess of standard oxalic acid, warming, and again adding permanganate until the end-point was reached. Gooch and Morgan volumetrically precipitated TeI_4 from tellurous acid solutions in the presence of 25 per cent. of sulphuric acid, using as an end-point the complete precipitation of the iodide by a potassium iodide solution.

Methods of separation of selenium and tellurium, the commercial methods of estimation of the elements employed at the refineries, and the uses of each element were also described. A. C.

116. Felspar for Glass-makers. F. C. FLINT (*J. Amer. Cer. Soc.*, 1923, **6**, 413).—The felspar should be ground to pass a 40-mesh sieve and not be finer than 80-mesh. The iron oxide content must be low and constant. Since the felspar was used primarily for additing alumina to the glass, the alumina content should be constant but need not be high so long as the price was adjusted accordingly. Silica might be considered only as a diluting material. The alkalis should be constant in amount and high enough to warrant the use of the felspar. Other impurities such as lime, magnesia, titania, etc., generally occurred in quantities too small to be worth consideration. Nevertheless, their amounts should be known in order to allow the batch composition to be calculated correctly.

F. W. H.

6—2

117. The Polarising Microscope as an Aid in Felspar Standardisation. H. C. ARNOLD (*J. Amer. Cer. Soc.*, 1923, **6**, 409).—Important problems arose in the study of felspars due to : (1) Accessory minerals, occurring with felspars, which were detrimental to their use in ceramic work; the most important of these were micas, garnets, tourmaline, and hornblende. (2) Free silica or quartz. (3) Differences in shapes and sizes of the grains produced by different methods of grinding. (4) The nature of the dark impurities, other than the minerals already mentioned, occurring in powdered felspar. (5) Variations in quality in different shipments of felspar.

Information was given as to the various ways in which the impurities in felspars might be recognised and estimated by using the petrological microscope.   F. W. H.

118. The Effect of Long Grinding on Quartz (Silver Sand). R. C. RAY (*Proc. Roy. Soc.*, 1923, **102**, [*A*], 640).—The densities of silver sand, both unground and after grinding in an agate mortar for fifteen hours, were determined. It was found impossible to obtain consistent results in the case of the ground sand when water was used in the determination of the volume, and trouble arose when the specific gravity bottle was used.
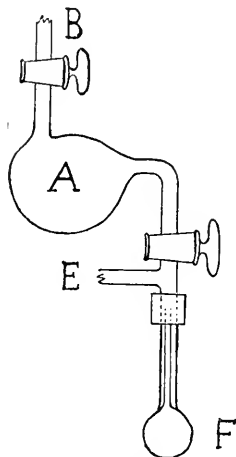
FIG. 61.

A small bulb, *F*, of about 10 c.c. capacity, was blown at the end of the capillary of internal diameter 0·5 mm. After steaming out, the bulb was heated at a temperature of 300° for twenty-four hours to eliminate contraction of the glass. The capacity was determined by filling with water, and the liquid used for determining the volume of the sand was redistilled carbon tetrachloride. All densities were determined at air temperature, 16° to 17·6°. The sand samples were dried at 150°.

The average values of the density referred to water at 4° were : silver sand (*a*) (unground), 2·638; (*b*) (ground), 2·528; silica glass (crushed), 2·208. Hence, the unground material had the higher density, and the fall in density on grinding showed that 25·7 per cent. of the quartz was converted from the crystalline to the vitreous condition.   V. D.

II.—Glass : Manufacture and Properties.

119. The Modern Glass Factory. W. S. MAYERS (*Glass Industry*, 1922, **3**, 129).—The ideal location for the glass factory was discussed and also labour problems, raw materials, power, and water supply. In connection with the factory buildings themselves, consideration was given to size, auxiliary equipment, air-ducts and stacks, nature of materials for construction of walls, roofs, floors, and windows, and facilities for railroad sidings. F. W. H.

120. Modern Glass Factory Equipment. W. S. MAYERS *Glass Industry*, 1923, **4**, 7).—Pot furnaces and small tanks did not justify expensive batch mixing and conveying systems, except perhaps where several small tonnage tanks were conveniently grouped, hand mixing if properly done being as good as mechanical mixing but laborious. Appliances for weighing and mixing included those with non-portable mixing drums discharging into elevators or conveyors, the batch materials being carried in batch cars with built-in scales, or hopper trucks passing over platform scales; or again all the operations of weighing, mixing, and transporting might be performed in a self-contained machine.

Unloading raw materials from the railway trucks might be carried out by power shovels in modern factories, and the materials charged

Fig. 62.

into hoppers from which conveyors or skip hoists transported them to the storage bins. The best arrangement was claimed to be a single combination hopper and elevator which could travel on a runway between the railway siding and the battery of hoppers, and so serve any hopper at will. If only one fixed elevator was possible, one conveyor would be necessary to discharge materials into the various bins. Outside spouting should be water-tight, and made of 8-gauge plate to withstand the scouring action of the sand.
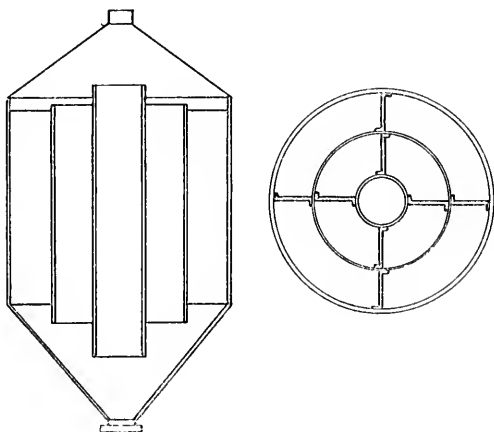
Three systems of batch conveyors included (1) batch cars running under elevated bins and discharging directly into furnace bins, (2) batch cars running under storage bins near the ground level, and

discharging into elevators at each furnace; (3) cars running under bins at any level and tipping into elevating and conveying system extending to furnace bins.   In view of the heavy structure required for the first type, and the dust formed in the operation of the second, the third system seemed to be most adaptable, in which the batch passed from the track hopper under the storage bins to the elevator boot by a short screw conveyor with dust tight casing, whilst a belt conveyor with travelling tripper and enclosed in dust-proof casing was used from the elevator to the various furnace bins whether they were centralised or isolated.

Furnace bins were usually constructed of steel plate to take twenty-four hours' supply, being 8 to 20 feet above the dog-house, and covered dust-tight.   Substructure which would inconvenience the furnace man must be avoided; cylindrical bins were superior to rectangular bins from a constructional point of view, and with the object of minimising segregation the author recommended the construction shown (Fig. 62.)   W. S.

121. Graphic Check on Glass Works Operation. W. J. KNOTHE (*Glass Industry*, 1923, **4**, 83).—Clear, concise, systematic and regular reports were needed to show rapidly any irregularities in the operation of the plant.   A chart could be drawn up to show the highest possible efficiency of any unit or of the whole plant; and such a chart which was in use for checking a glass tank and producers was given in illustration.   The chart would be useful when building a new factory or designing extensions, and in determining the size of the tank for a given production; but its real value lay in checking daily operations, especially when a line was drawn from the point representing the normal week's production (of glass) and consumption (of fuel) to the zero.   From this, the daily output could be checked, and deficiencies more easily correlated with their causes, whether they were furnace troubles or manipulation faults.   W. S.

122. Making Hollow Panes of Glass.   I. M. KIRLIN (U.S.A. Pat., No. **1448351**, March 13th, 1923.   Filed September 29th, 1921, No. 504157).—The invention relates to a method of making
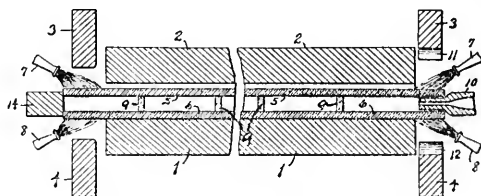
FIG. 63.

glass panes composed of sheets separated from one another but joined at their edges, the space between the sheets being exhausted of air.

Apparatus for making the panes comprises a base, **1,** and a

platen, 2, movable relatively to each other and mounted in a furnace. Along the edges of these members are two vertically movable frames consisting of bars, 3, 4, which can be moved to and from one another. Gas burners, 7, 8, direct flames on to the edges of glass sheets, 5, 6, which are arranged on the base, 1, small posts, 9, of heat-resisting material being used to space the sheets apart.

When the glass is softened, the edges are united by being pressed between the bars, 3, 4, and the platen presses the sheets against the bars, 9. A tube, 10, of glass or metal is enclosed in one of the sealed edges and provides a vent for exhausting the air from between the sheets.   G. D.

123. Manufacture of Vacuum Flasks. C. LOECHNER (*Sprechsaal*, 1923, **56**, 114).—An account of the mode of manufacture in Germany. The batch recommended was Martinroda sand 100; soda ash (98—100%) 32; limespar 21·8; the sand containing 3·4 per cent. of alumina. If this glass was too hard, the lime could be reduced to 18·6. It was, however, vital to have a good glass, both chemically and thermally durable. The flasks must be of even wall thickness and be well annealed.

The inner and outer flasks were then worked up in the lampworker's room, the outer flask at both neck and base, the inner flask at the neck only. The work here being specialised, the staff should not be changed. After cracking-off with a diamond and a long flame, the flasks were placed in boxes. The length of the neck of the inside flask should be four to five millimetres longer than that of the outer flask. After cracking-off, the flasks must be free from dirt, the inner flask being wiped with a cloth, and the outer one washed with distilled water. The flasks were then placed, the one inside the other, and kept in position with spirals or asbestos, the latter being generally preferred. The workman next placed the inverted bottle in a container lined with asbestos, and the edge of the bottom was softened by means of a blast lamp, the softened glass being drawn out with tweezers, whilst air was blown into the bottle through a hole in the container, in order to shape the base. After removal from the container, a capillary glass tube was melted into the bottom. The neck was next fashioned by placing the bottle in the container with the bottom downwards, and softening the two necks with the blow lamp whilst blowing in air through the capillary to maintain a regular thin wall at the junction. After annealing, silvering was effected by introducing the silver solution through the capillary, maintaining the bottle in motion between rollers, and raising the temperature to no more than 35°. The sediment and water were cleaned off by means of air pressure, the capillary being freed from any silver deposit before drying, which was carried out in different ways. Evacuation followed the normal processes in use to-day, leaks in the bottle being tested by mercury gauges. The final fusing of the capillary was very important and needed great care. The test on each bottle was that water, at 95° when introduced, should still be at least at 45° after standing twenty-four hours.   W. S.

124. Making Bent Glass Rods at the Furnace. V. DURAND (U.S.A. Pat., No. **1451361**, April 10, 1923. Filed November 14th, 1921, No. 514858).—A method of making bent glass rods, intended
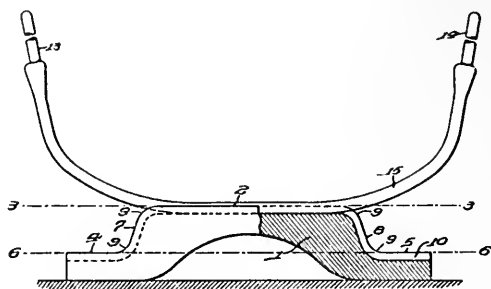
FIG. 64.

for use in the manufacture of artificial silk, consists in drawing the rod in the usual manner and while it is still soft, laying it on a metal former, 1, so that it sags down to shape. The former has a groove to guide the rod and is heated to a suitable temperature.

                                                                G. D.

125. Producing Spun Glass. G. VON PAZSICZKY (U.S.A. Pat., No. **1427014**, August 22nd, 1922. Filed August 5th, 1921, No. 495229).—An improved apparatus for the production of spun glass comprises a receptacle, filled with molten glass, having outflow orifices in its bottom plate, and a revolving cylinder under the receptacle on the surface of which drops of glass issuing from the orifices adhere. The drops are drawn out into threads by the rotation of the cylinder and are wound on its surface.   G. D.

126. Glass for Windshields. L. WINTER and B. W. SCHNUR (U.S.A. Pat., No. **1438470**, December 12th, 1922. Filed January 29th, 1920, No. 354829).—A substitute for plate glass, for use in automobile windshields, consists of crystal sheet glass ground and polished to remove surface waves. The grinding is not continued right to the edge of the pane, however, but an edge, about 1 inch wide, and of the original thickness of the sheet is left. This thicker edge strengthens the sheet and also fits the channels of the windshield.   G. D.

127. Process of Making a Fused Bifocal. L. W. BUGBEE, Indianapolis, Indiana, U.S.A., Assignor to the FRANKLIN OPTICAL Co., Indianapolis, Indiana (U.S.A. Pat., No. **1450711**, April 3rd, 1923. Filed April 21st, 1921, No. 465582).—The process relates to a new method of fusing-in the reading segment of flint glass, and overcomes what is said to be a difficulty, namely, the predominance of striæ, bubbles, and other defects in flint glass such as is ordinarily used in this process.

The usual recess is ground into the plate of crown glass, and polished as in the ordinary process. This recess is then filled with

rounded particles or nodules of flint glass, and the whole is subjected to such a temperature as will melt the flint glass and cause the nodules to fuse together, and to the crown glass blank, thus producing a homogeneous solid segment of flint glass.   The compound blank is then ground and polished in the usual way.   S. E.

128. Glass Ovenware and Holder Therefor. H. NEGBAUR, New York, U.S.A., Assignor to E. and J. BASS, INC., New York (U.S.A. Pat., No. **1450330**, April 3rd, 1923. Filed November 25th, 1921, No. 517424).—The yellow colour of certain low-expansion glassware which is used for cooking purposes does not harmonise with the silver and nickel frames which are often used with such ware.   This discordant effect may be overcome by applying to the outer surface of such ware a metallic pigment mixed with lead borosilicate, and firing the ware to about 800° F. for three hours. The pigment thus enters the glass, giving it a permanent colour, and rendering it somewhat translucent.   S. E.

129. Phosphoric Acid Glasses and Glazes. H. FRITZ (*Sprechsaal*, 1918, **51**, 149, 153, 157).—An account of the preparation and some properties of a series of glasses containing phosphoric oxide but no silica.   In a first series, A, phosphoric oxide was used as a batch material; whilst in a second series, B, various phosphates were employed.   Each of the glasses of the A series contained basic oxides in one of the following molecular ratios :

    (a) $0.1K_2O, 0.1CaO, 0.8PbO$ (low alkali, high lead oxide).
    (b) $0.3K_2O, 0.4Na_2O, 0.1CaO, 0.2PbO$ (high alkali, low lead oxide).
    (c) $0.2K_2O, 0.2Na_2O, 0.2CaO, 0.4PbO$ (medium).

These bases were combined with each of the following seven acidic groups in turn :

I, P_2O_5; II, $0.1Al_2O_3, P_2O_5$; III, $2P_2O_5$; IV, $0.2Al_2O_3, 2P_2O_5$; V, $3P_2O_5$; VI, $0.3Al_2O_3, 3P_2O_5$; VII, $0.15Al_2O_3, 3P_2O_5$.

By this means 21 glasses resulted, as, for instance,
$$0.1K_2O, 0.1CaO, 0.1Al_2O_3, 1P_2O_5,$$
which may be shortly indicated as $AIIa$, and similarly for the others. The appearance of the glasses of the A series, which were melted in a fireclay crucible in a muffle furnace at about S.K. 03a was : brilliant appearance, AIa, $AIIa$, $AIIIa$, AIc, $AIIc$, $AIIIc$; clear, $AIVa$, AVa, AIb, $AIIb$, $AIIIb$, $AIVb$, AVb, $AIVc$, AVc, $AVIIc$; matt and rough, $AVIa$; not melted $AVIIa$, $AVIb$, $AVIIb$, $AVIc$. High lead oxide content tended to give greater brilliance, whilst the presence of the alumina in conjunction with high acid content was not favourable to melting.
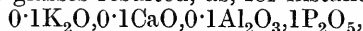
    The glasses having a high refractive index were AIa, AIc, $AIIa$, $AIIc$, $AIVa$, $AIVc$, $AIVb$, and these would probably be useful for optical glass or artificial gems.   Some of the glasses were attacked when exposed to the atmosphere, namely, $AIIIa$ and AVa a little,

AIIIc, AVc and AVIIc rather more, AIIIb, and AVb badly.   The durability of a number of the brilliant glasses was tested by boiling in water for an hour, and in 4 per cent. acetic acid for half an hour. The following withstood both tests well: AIIa, AIIIa, AVIa, AVIb, AVIIc.   Glasses AIa, AIVc, AVb, AVIc, AVIIb withstood the first test, but were acted on by the acid, whilst AVa and AVIc were attacked in both cases.   Thus, in the phosphoric anhydride series the best results were obtained with a low acid and a high lead content.

In the second series, B_1, the phosphates of barium, lead, calcium, potassium, sodium ($Na_4P_2O_7$), and zinc were employed, to give the following series of glasses :

I. $RO,0{\cdot}33P_2O_5$

(a) $PbO,0{\cdot}33P_2O_5$

(b) $\left.\begin{array}{l}0{\cdot}5K_2O\\0{\cdot}5PbO\end{array}\right\}0{\cdot}33P_2O_5$

(c) $\left.\begin{array}{l}0{\cdot}5Na_2O\\0{\cdot}5PbO\end{array}\right\}0{\cdot}33P_2O_5$

(d) $\left.\begin{array}{l}0{\cdot}5BaO\\0{\cdot}5PbO\end{array}\right\}0{\cdot}33P_2O_5$

(e) $\left.\begin{array}{l}0{\cdot}5ZnO\\0{\cdot}5PbO\end{array}\right\}0{\cdot}33P_2O_5$

(f) $\left.\begin{array}{l}0{\cdot}5CaO\\0{\cdot}5PbO\end{array}\right\}0{\cdot}33P_2O_5$

II. $RO,0{\cdot}58P_2O_5$

(a) $\left.\begin{array}{l}0{\cdot}3K_2O\\0{\cdot}3Na_2O\\0{\cdot}4PbO\end{array}\right\}0{\cdot}58P_2O_5$

(b) $\left.\begin{array}{l}0{\cdot}3K_2O\\0{\cdot}3Na_2O\\0{\cdot}1ZnO\\0{\cdot}3PbO\end{array}\right\}0{\cdot}58P_2O_5$

(c) $\left.\begin{array}{l}0{\cdot}3K_2O\\0{\cdot}3Na_2O\\0{\cdot}1BaO\\0{\cdot}3PbO\end{array}\right\}0{\cdot}58P_2O_5$

(d) $\left.\begin{array}{l}0{\cdot}3K_2O\\0{\cdot}3Na_2O\\0{\cdot}1CaO\\0{\cdot}3PbO\end{array}\right\}0{\cdot}58P_2O_5$

III. $RO,0{\cdot}66P_2O_5$

(a) $\left.\begin{array}{l}0{\cdot}5K_2O\\0{\cdot}5PbO\end{array}\right\}0{\cdot}66P_2O_5$

(b) $\left.\begin{array}{l}0{\cdot}5K_2O\\0{\cdot}1CaO\\0{\cdot}4PbO\end{array}\right\}0{\cdot}66P_2O_5$

(c) $\left.\begin{array}{l}0{\cdot}5K_2O\\0{\cdot}1ZnO\\0{\cdot}4PbO\end{array}\right\}0{\cdot}66P_2O_5$

(d) $\left.\begin{array}{l}0{\cdot}5K_2O\\0{\cdot}1BaO\\0{\cdot}4PbO\end{array}\right\}0{\cdot}66P_2O_5$

In a second set of phosphate melts alumina was added to the above in the proportion of $0{\cdot}15$ molecule of Al_2O_3.   The melting results were :

	Clear.	Partly clear.	Unmixed	Cloudy.	Sintered mass.	Crystalline.
Without alumina	BIId	BIIIb	BIa	BIIa	BIb	BIc
		BIIc	BIf	BIIb	BIc	BId
		BIIIc			BId	BIc
					BIe	BIIIa
					BIIf	
					BIIId	BIIId
With alumina	BIIb	BIIc	BIa	BIIa	BIb	BIa
	BIId	BIIIa	BIb		BIe	BIc
	BIIIb	BIIIc	BIIIa		BId	BId
					BIe	BIe
					BIf	BIf
					BIIId	BIIId

Here the alumina had a tendency to produce clear glasses.   The bases had approximately the same order of fluxing action as in silicate glasses, that is, in order of increasing refractoriness, PbO,Na_2O,K_2O and BaO, whilst ZnO and CaO were of about the same order of fusibility.   A. C.

130. Method for Making Articles of Transparent Silica.
BRITISH THOMSON-HOUSTON Co., LTD., London, and the GENERAL
ELECTRIC Co., Schenectady, New York, U.S.A. (Brit. Pat., No.
189926, October 6th, 1921).—A method of making shaped articles,
rod, or tube of transparent silica consists in fusing the silica in a
vacuum, cooling it to a congealing temperature, transferring this
vacuum-fused silica to a heating space under atmospheric pressure,
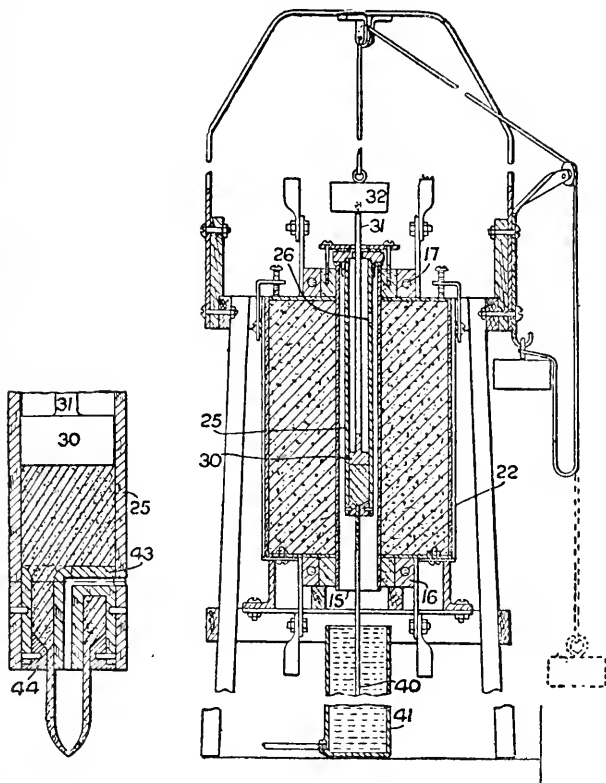
FIG. 65.

reheating the silica to a plastic state, and then moulding it to a
desired form, or extending it through a die, by applying pressure.
The silica is first freed from bubbles by melting it in a vacuum and
subjecting it to pressure in the manner described in Specification
188451. The resulting mass of glassy silica is transferred to a
furnace, shown in Fig. 65, comprising a carbon tube, 15, connected
to water-cooled terminals, 16, 17, by which the heating current
is supplied, and surrounded by a packing of charcoal or other heat-
insulating material in an asbestos receptacle, 22. The silica is

contained in a graphite crucible, 25, situated within the heater and provided with a graphite piston, 30, the rod, 31, of which is loaded with a weight, 32. The crucible has a vent, 26, communicating with the surrounding space which is open to atmospheric pressure. The weight on the piston pressing on the plastic silica eliminates bubbles and produces a clear glassy mass. The bottom of the crucible may be fitted with a die so that the silica can be extruded as a rod or cane, 40, into a vessel, 41, containing water. In making quartz tubing, the bottom of the crucible is provided with a die, 44, having an opening into which fits a tubular cone, 43, communicating with the atmosphere. Before the furnace is put into operation and before silica is placed therein, the graphite crucible, piston, and die, are fired in a vacuum to about 2000°. Mineral matter is thus volatilised from the crucible and furnace members which come into contact with the silica, and the final product is obtained free from cloudiness or opacity.   H. G. C.

131. Method of Freeing Molten Silica from Air Bubbles.
BRITISH THOMSON-HOUSTON CO., LTD., London, and the GENERAL
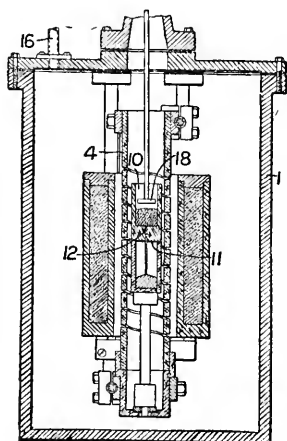
FIG. 66.

ELECTRIC Co., Schenectady, New York, U.S.A. (Brit. Pat., No. **191463**, October 11th, 1921).—A method of freeing molten silica from air bubbles consists in extruding the silica under pressure through a narrow slit. The furnace for melting the silica consists of a cylindrical heater, 4, enclosed in a tank, 1, fitted with a pipe, 16, through which the enclosed air can be evacuated to enable the fusion to be carried out under reduced pressure. A cylindrical crucible, 10, located within the heater is divided into two compartments separated by a transverse wall, 11, formed with a slit, 12. Pure silica, such as quartz crystal, is placed in the upper compartment and heated, under reduced pressure until it is plastic, at about 1750°. The fused mass is then caused by pressure transmitted through a graphite piston, 18, to flow through the slit, 12, into the lower compartment. The crucible is made of material which is inert to molten silica, such as graphite which has been fired at a high temperature.   H. G. C.

132. Process for Making Transparent Fused Silica. H. O. BARNARD, and H. GEORGE, both in Paris, Assignors to Soc. ANON. QUARTZ ET SILICE, Paris (Brit. Pat., No. **190476**, December 8th, 1922. Convention date, December 16th, 1921. Not yet accepted). —A process of manufacturing fused silica which shall be transparent and free from bubbles consists in agglomerating the raw material, reduced to fine powder, with gelatinous silica and then

compressing it into moulds of the desired shape at a pressure of about 200 kg. per square centimetre. The moulded mass is next heated at about 150° to get rid of moisture, and is then fused in an electric furnace. Agglomeration of the raw material is facilitated by first transforming it into cristobalite by heating at about 1500°.

Another patent by the same inventors on the same subject is as follows : (Brit. Pat., No. **190477**, December 8th, 1922. Convention date, December 16th, 1921. Not yet accepted).—Compact siliceous rocks of a high degree of purity and preferably containing no microcrystalline cement are melted. The rock is cut into cylinders which are perforated axially so that they can be threaded on the carbon electrode of the furnace. H. G. C.

133. The Cobalt Oxide Colours. Dr. RÜGER (*Ker. Rundschau*, 1923, **31**, 79, 87, 99, 110).—The characteristic colours obtained by fusing the oxides of many metals with cobalt oxide had been systematically examined by J. A. Hedvall. Thus, Rinman's green was shown to be an isomorphous mixture of cobalt zincate (CoO,ZnO) with zinc oxide, which could not be chemically separated. The green mass, obtained by heating cobalt oxide with stannic oxide, was coloured by the formation of green cobalt orthostannate (Co_2SnO_4). Hedvall further showed that Thenard's blue, which resulted when Al_2O_3 and CoO were fused together, was due to the production of blue Al_2O_3,CoO, an oxide of the *spinel* group, to which class Cr_2O_3,CoO, Fe_2O_3,CoO, and Mn_2O_3,CoO also belonged. Thenard's blue was examined in greater detail by the author, who proved that the green intermediate product first formed on fusing the mixture Al_2O_3,0·5CoO at 900° was a solid solution of CoO in CoO,Al_2O_3.

By heating the mixture $2SiO_2$:1CoO at 900°, a bluish-violet mass was soon obtained, the colour persisting on further heating. The colouring agent could be dissolved out by dilute acids and was found to be cobalt metasilicate, $CoSiO_3$. The orthosilicate was prepared by heating the mixture $1SiO_2$:2CoO for six hours at 1000°, cooling rapidly, crushing, and removing free SiO_2 with potash and then free CoO with hydrochloric acid. On washing in water and drying, a ruby-red product, which proved to be Co_2SiO_4, was obtained. Zinc metasilicate was prepared by heating the mixture $2SiO_2$:1ZnO for one hour at 900°, and treating the resultant for several hours with alkali solution on the water-bath. When an oxide mixture of the composition $1SiO_2$:2ZnO was heated for two hours at 1200° and the products were digested with acetic acid on the water-bath, the yellowish-white orthosilicate, Zn_2SiO_4, remained. By fusing together zinc oxide, cobalt oxide, and silica with the zinc oxide in excess of the molecular proportion 1 : 1 : 1 at 950° a green product was obtained. When zinc metasilicate was heated for two hours at 900° with increasing amounts of cobalt oxide a more or less intense blue colour resulted, which was most pronounced at the ratio $1ZnSiO_3$:1CoO. When more cobalt oxide than this was employed, a darker mass resulted, from which the blue colouring matter could be dissolved out from the excess CoO ; this colouring

agent proved to be zinc cobalt orthosilicate, $ZnCoSiO_4$. If Na_2O, K_2O, SnO, or BaO were fused with silica and cobalt oxide, all in unimolecular ratio, clear blue masses were obtained at 950° which, on pouring into water, crushing, and drying were found to be equivalent to smalt. The mixture $CoO:SiO_2:SnO_2$, heated for one, two, or three hours, at 900° gave a lilac-coloured mass, which proved to be a mixture of cobalt meta- and ortho-silicates with SnO_2. Neither nickel oxide, ferrous oxide, nor copper oxide on heating with silica at 900° to 1200° gave any compound, but cadmium oxide readily gave the orthosilicate Cd_2SiO_4 at 900°.

A. C.

134. Decolorising Borosilicate Glasses. W. C. TAYLOR, Corning, New York, U.S.A., Assignor to the CORNING GLASS WORKS, New York (U.S.A. Pat., No. **1449793**, March 27th, 1923).—With an acidic glass such as borosilicate glasses, manganese dioxide, nickel oxide, or selenium could not be used as decolorisers, since they gave a yellow to dull amber colour instead of pink, and the colour produced by the iron oxide was yellow instead of green. Neodymium oxide (Nd_2O_3), although ineffective in ordinary glasses, was well suited to decolorise these acidic glasses on account of its peculiar absorption of the yellow colour. The percentage compositions of typical glasses to which it applied were as follows :—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.
SiO_2 ...	70	70	60	60	80	85	90	61	70	80·6	80·9	90	90
B_2O_3 ...	24	15	20	30	6	5	2	11	20	13	12·9	6	5
Na_2O .	5	15	10	10	12	10	8	$8\frac{1}{4}$	4	4·4	4·4	3	—
Al_2O_3 .	1	—	10	—	2	—	—	$6\frac{3}{4}$	6	2	1·8	1	2
PbO ...	—	—	—	—	—	—	—	13	—	—	—	—	—
Li_2O ...	—	—	—	—	—	—	—	—	—	—	—	—	3

Although antimony oxide (Sb_2O_3) should not be present in large amount, nor, indeed, apparently any other oxides of the fifth group, small amounts of arsenic or antimony were not injurious. Whilst it was difficult to obtain pure neodymium oxide, the commercial product " didymium oxide " could be used, or any material containing neodymium oxide, provided that the other substances present neither nullified the colouring action of the neodymium nor destroyed the acid character of the glass.

A 0·5 to 1 per cent. of neodymium oxide was added to the batch as decoloriser, preferably to an oxidising batch (such as one containing nitre). To obtain a pink coloration, up to 5 per cent. of neodymium oxide was used to replace silica in the glass, if the latter admitted of the replacement. In such a case, glass II would become SiO_2 65 per cent., B_2O_3 15, Na_2O 15, Nd_2O_3 5. Generally, borosilicate glasses conforming to the following rules would operate as outlined.

A. Silica content not less than 80 per cent. (examples V, VI, VII, X, XI, XII, and XIII).

B. Silica content not less than 75 per cent., and boric oxide not less than 40 per cent. of the constituents other than silica (examples VI, X, XI, XII, XIII).

C. Silica content not less than 70 per cent., and boric oxide not less than the alkali (examples I, II, VIII, IX, X, XI, XII, XIII); or boric oxide not less than 50 per cent. of the total constituents other than silica (examples I, II, IX, X, XI, XII, XIII).

D. Boric oxide not less than 50 per cent. of the total constituents other than silica (examples, all except V and VI).

E. Silica not less than 60 per cent., boric oxide not less than 25 per cent. of the total constituents other than silica (examples I to XIII inclusive). W. S.

135. Temperature Distribution in Solids during Heating or Cooling. E. D. WILLIAMSON and L. H. ADAMS (*Phys. Rev.*, 1919, **14**, 99).—In the course of research on the problem of annealing optical glass, the authors found it necessary to investigate the above distribution. Equations were derived for the temperature distribution in several simple shapes when the surface was heated or cooled at a uniform rate. In all cases, the curves showing the relation between the temperature and the depth were parabolic. The application of the results to the case of solids of any size and thermal conductivity was illustrated. Equations were also derived for the case of sudden heating of the surface. A method of measuring the thermal conductivity of a substance, which involved the determination of the temperature–time relation at the centre of a heated block, resulted from the equations, but was not practically developed. J. R. C.

136. The Annealing of Glass. L. H. ADAMS and E. D. WILLIAMSON (*J. Franklin Inst.*, 1920, **190**, 597, 835).—These papers correlated the results of several earlier investigations and described their application to the actual annealing of glass on a large scale. Before describing the method used in determining the correct procedure for annealing glass, the generation and release of internal stress were considered. When a glass slab was heated at both faces the outside layers entered into a state of compression and the inside layers into a state of tension, a neutral zone existing between the two. When the slab was allowed to cool, the thermal gradient and the stresses disappeared. The reverse phenomena occurred when the glass was initially cooled. Similarly, if a temperature gradient existed in a slab free from stress, for example, in the case of a glass cooled at a constant rate from a high temperature, the removal of the temperature gradient would cause stresses equal and opposite in sign to those which would be produced by the establishment of the same temperature gradient. When a glass was cooled at a constant rate, the temperature distribution ultimately became parabolic, and if this condition had been attained while the glass was still capable of yielding to stresses, the removal of the gradient when the exterior had arrived at room temperature would involve the production of stresses. The strain caused by these stresses was called " ordinary " strain, and that introduced by the establishment of a temperature gradient when a solid was beginning to cool was called " reverse "

TABLE I.

Kind of Glass	Chemical Composition.									Optical Properties.			Mechanical Properties.	
	PbO.	CaO.	BaO.	ZnO.	Na$_2$O.	K$_2$O.	Al$_2$O$_3$.	B$_2$O$_3$.	SiO$_2$.	n_D	ν	B	Modulus of Compressibility. kg./cm.²	Modulus of Rigidity kg./cm.²
Borosilicate crown	—	—	4	—	9	8	—	12	67	1·516	62	$2·85\times10^{-7}$	$0·43\times10^{6}$	$0·29\times10^{6}$
Ordinary crown ...	—	12	—	—	14	1	—	—	73	1·523	59	$2·57\times10^{-7}$	$0·46\times10^{6}$	$0·28\times10^{6}$
Light barium crown	—	—	29	11	3	5	1	4	47	1·574	57	$2·81\times10^{-7}$	$0·52\times10^{6}$	$0·30\times10^{6}$
Heavy barium crown	—	—	43	8	—	—	3	6	40	1·608	57	$2·15\times10^{-7}$	$0·53\times10^{6}$	$0·29\times10^{6}$
Barium flint	24	—	15	8	3	4	—	—	46	1·606	44	$3·10\times10^{-7}$	$0·42\times10^{6}$	$0·26\times10^{6}$
Light flint	35	—	—	—	6	5	—	—	54	1·573	42	$3·20\times10^{-7}$	$0·35\times10^{6}$	$0·24\times10^{6}$
Medium flint	48	—	—	—	3	4	—	—	45	1·616	37	$3·13\times10^{-7}$	$0·34\times10^{6}$	$0·22\times10^{6}$
Heavy flint	52	—	—	—	3	3	—	—	42	1·655	33	$2·67\times10^{-7}$	$0·34\times10^{6}$	$0·22\times10^{6}$
Extra heavy flint	69	—	—	—	—	3	—	—	28	1·756	27	$1·22\times10^{-7}$	$0·32\times10^{6}$	$0·20\times10^{6}$

strain. If an unstrained piece of glass, initially without thermal gradient, were cooled from a temperature below the softening point, the two strains balanced and no permanent strain was introduced. In general, the strain remaining in a block of glass was equal and opposite in sign to the reverse strain lost by viscous yielding in the early stages of the cooling process. Thus the problem of annealing could be divided into two parts : (1) a determination of the temporary stresses produced in a block of glass when heated or cooled in a given way; (2) a measurement of the rate of release of stress at various temperatures.

It was shown that the difference between the refractive indices, n_y and n_z, for light vibrating in two perpendicular directions in the glass could be expressed by the equation $n_y - n_z = BF$, where F was the thrust and B a constant depending on the optical and elasticity constants of the glass. The values of B, the birefringence due to 1 kg./cm.^{2} tension, for various glasses were measured by the authors (see Table I). A quartz wedge compensator was used to determine the optical path difference and the birefringence calculated by dividing by the thickness of the glass traversed.

The apparatus for the measurement of the rate of release of stress was fully described. The specimens of glass used were 2 cm. in thickness and 8 cm. in length and breadth. This shape was preferred to a cylinder, as the path difference along the axis of a cylinder was zero, and therefore readings in that case would have had to be taken at some undetermined point not on the axis. The large dimensions of the slab allowed the end effects to be ignored. The strained specimen was maintained at the temperature at which observations were to be made for twenty minutes before the rate of release was determined. Readings were continued until a path difference of about 5 $\mu\mu$ per cm. length was reached. Results at three or more temperatures were given for each of the glasses mentioned. It was found that, approximately, the rate of release of stress was proportional to the square of the stress. The assumption of this law led to the formula $\dfrac{1}{F} - \dfrac{1}{F_0} = ABt$, in which F_0 was the stress at the time $t=0$, and A was a constant. This could be converted into $\dfrac{1}{\delta} - \dfrac{1}{\delta_0} = A't$, where δ was the path difference, and $A' = A/l$, l being the length of the specimen. The quantity A indicated the variation of stress with time, and was called the annealing constant. The values of A, A', and l for the various glasses are given in the table on p. 94.

As the formula was empirical, a special series of experiments at low temperatures was undertaken with light flint glass to see whether it was valid in this case. It was concluded that at very low temperatures and for the initial part of the release of internal stress the formula failed to represent the relation between stress and time, although it was quite satisfactory in the temperature range which was of greatest practical importance.

The authors' results confirmed Twyman's statement (this Journal,

TABLE II.

Kind of Glass.	Reference No.	Temperature.	A'.	l.	A.
Borosilicate crown ...	1	480°	0·0000072	7·5 cm.	0·000054
		500	0·000022		0·00017
		530	0·00021		0·0016
Ordinary crown	2	450	0·0000034	10·8 cm.	0·000037
		470	0·000024		0·00026
		490	0·000049		0·00053
		500	0·000105		0·00113
		515	0·00040		0·0043
Light barium crown .	3	500	0·0000113	7·5 cm.	0·000085
		516	0·000028		0·00021
		540	0·00020		0·0015
Heavy barium crown	4	540	0·0000062	7·5 cm.	0·000047
		565	0·000034		0·00026
		590	0·00047		0·0035
Barium flint	5	450	0·000022	7·5 cm.	0·00017
		470	0·00013		0·00098
		490	0·00031		0·0023
Light flint	6	385	0·000080	10·0 cm.	0·00080
		400	0·00017		0·0017
		415	0·00046		0·0046
Medium flint	7	306	0·000000102	7·5 cm.	0·00000077
		374	0·0000106		0·000080
		390	0·000040		0·00030
		406	0·00017		0·0013
Heavy flint	8	375	0·000029	7·5 cm.	0·00022
		385	0·000075		0·00056
		400	0·00025		0·0019
Extra heavy flint......	9	350	0·000046	7·5 cm.	0·00034
		370	0·00021		0·0016

TRANS., 1917, **1**, 61) that the mobility of glass was an exponential function of the temperature (θ). The equation $\log A = M_1\theta - M_2$ was found to hold; and thus the time taken to reduce the stress from any initial to any final value could be calculated. The constants M_1 and M_2, and the annealing temperatures for various times are given below, the initial and final stresses being 50 $\mu\mu$ and 2·5 $\mu\mu$ per cm.

TABLE III.

Glass.	M_1.	M_2.	Annealing Temperature.						
			2 min.	10 min.	1 hour.	5 hours.	1 day.	1 week.	1 month.
1	0·030	18·68	599°	575°	549°	526°	503°	475°	454°
2	0·029	17·35	573	549	522	498	475	446	424
3	0·032	20·10	606	584	559	538	516	490	470
4	0·038	24·95	638	619	599	580	563	540	524
5	0·028	16·28	556	531	503	478	454	424	401
6	0·033	15·92	461	439	416	395	374	348	329
7	0·038	18·34	464	445	425	407	389	366	350
8	0·037	17·51	454	435	414	395	377	354	337
9	0·033	15·03	434	412	389	368	347	321	302

The first paper concluded with a comparison of the results with those obtained by previous investigators. In most cases, chemical compositions had not been given, and in all cases there was insufficient cooling data.

In the second paper, the practical aspect of annealing was considered. As the authors were mainly concerned with optical glass, they concentrated on this although the discussion was applicable to any kind of glass. They suggested that optical glass should be regarded as annealed when the maximum path difference was reduced to $10 \mu\mu$ per cm. For slabs of glass this would limit the path difference along the middle to $5 \mu\mu$ per cm. Since unannealed optical glass was seldom strained to an extent of more than $50 \mu\mu$ per cm., the " annealing time " at a given temperature, in this case, was defined as the time required to reduce the stress from $50 \mu\mu$ to $2 \cdot 5 \mu\mu$. The " annealing temperature " for a given time was similarly defined. The " annealing range " was taken as that $150°$ interval of temperature lying immediately below the temperature at which the annealing time was two minutes.

It was shown that in order to obtain the glass as free from stress as possible it was actually necessary to prevent the release of stress while the glass was being cooled. This was done in the older method of annealing by reducing the initial stress, at the annealing temperature, to such a small amount that it was immaterial if it were all lost. The permanent strain established by the final removal of the temperature gradient was then small enough to be within the permissible limits. In their improved method of annealing, the authors maintained the glass for a sufficient time at a temperature at which it took several hours to anneal, and then cooled it fairly rapidly. In this case, the initial strain when the glass started to cool was fairly high, but as the viscosity was also high, little strain was lost in cooling, and little permanent strain resulted. This method possessed many advantages over the other. It was easier to keep an annealing furnace at a constant temperature than to cool it at a given constant rate; the total time taken to anneal was less; there was less danger of overheating the glass; and the danger of devitrification was less.

The rate of cooling depended largely on the method of annealing. Two special cases for each method were mathematically discussed. These were (a) for cooling at a constant rate, (b) for cooling at a rate which increased in geometrical ratio. In the method I (a), the final stress was the same as that which would be established by heating at the same rate, and the birefringence was shown to be $\Delta n = 4 \cdot 6 \mathrm{B} h a^2 = ch$ where h was the cooling rate, and a the semi-thickness of the slab, c, therefore being a constant equal to $4 \cdot 6 \mathrm{B} a^2$. Slabs of optical glass 2 cm. thick annealed by this method could thus be cooled at the rate of $23°$ per hour, the rate of cooling varying inversely as the square of the thickness, if there was to be a final strain of $5 \mu\mu$ per cm. This rate should be maintained throughout the annealing range, after which the cooling could be accelerated. Case I (b) was more complex, but it was shown that for a similar piece of glass to possess the same residual strain, if the rate were to be doubled every $20°$, the initial rate of cooling should be $2 \cdot 8°$ per hour. Methods II (a) and II (b) were still more complicated, as the initial strain at the annealing temperature was not zero. It was shown that if the

permissible residual strain was $5 \mu\mu$ per cm., the glass should be maintained at the annealing temperature until the strain was $2\cdot5 \mu\mu$ per cm. The total time taken to anneal by method II (a) was least if the annealing temperature was so chosen that the annealing constant was equal to $0\cdot037/c$, and the cooling rate $9\cdot0/c$ degrees per minute for a range of 90°. Afterwards the cooling rate could be increased to $10/a^2$. For method II (b), if the cooling rate was to be doubled every 20°, the annealing constant should be $0\cdot047/c$, and the initial rate of cooling $5\cdot2/c$ degrees per minute. The minimum times taken to anneal a slab of glass 1, 2 cm. thick, by the four methods were calculated to be $6\cdot5$, $10\cdot3$, $4\cdot4$, and $3\cdot4$ hours respectively.

Annealing schedules were drawn up for slabs of varying thickness of the nine glasses previously mentioned, method II (b), which was considered best for optical glass, being employed. An actual record of the annealing of the slab of glass 1, from the cold start until the glass was taken out of the furnace was given. The total time was four hours fifty minutes, the glass being held at 542° for seventy-five minutes. The procedure for plate glass differed only in the permissible extent of the residual strain; $50 \mu\mu$ per cm. was suggested for this. The problem of annealing other kinds of glass was complicated by the variety of compositions and shapes. For lime–soda–silicate glasses, the " annealing temperatures " given by English and Turner (this Journal, TRANS., 1918, **2**, 90; 1919, **3**, 125), if compared with the results given above, would provide data for annealing by method II. A limiting strain of $50 \mu\mu$ per cm. was suggested, the complication introduced by the various shapes by treating the article as a slab of thickness equal to double the maximum thickness of the article.

Finally, a number of equations were presented suitable for calculating the stresses due to heating or cooling various simple shapes of glass. Throughout the investigation it had been assumed that the thermal conductivity and expansion did not change with temperature. This was justified, at temperatures such as were attained in method II, by comparison of the results of calculations with experiment, although it would probably not be the case at higher temperatures.   J. R. C.

137. A Mathematical Note on the Annealing of Glass. E. D. WILLIAMSON (*J. Wash. Acad. Sci.*, 1922, **12**, 1).—The equations representing deductions from experimental data in the preceding abstract were more rigorously developed, and this necessitated alterations in the annealing temperature and cooling rate in method II (b). The total time of annealing was thereby reduced 15 per cent. From the new final equations, the annealing temperature was so chosen that the annealing constant was equal to $0\cdot075/c$. Before cooling the strain had only to be reduced to $0\cdot725$ of the permissible strain, instead of to the half value as formerly, and the rate of cooling could be slightly greater.

J. R. C.

138. New Methods of Annealing Optical Glass. G. GUADET (*Revue d'Optique*, 1922, **1**, 184, 363).—A very lengthy summary of the work of Adams and Williamson. Reference was also made to work by A. A. Lebedeff at the Optical Institute of Petrograd (Cf. this Journal, ABS., 1922, No. **114**; 1923, Nos. **136** and **137**).

<div align="right">J. R. C.</div>

139. The Double Refraction of Unannealed Glass. H. SCHULZ (*Phys. Zeitsch.*, 1912, **13**, 1017).—**The Dependence of the Double Refraction of Optical Glasses on the Chemical Composition and the Shape.** E. ZSCHIMMER and H. SCHULZ (*Annalen der Physik*, 1913, **42**, 845).—Both these papers deal with the same investigation. The latter is more detailed and contains more information. The most important early investigation of the double refraction of glass was made by Neumann, who was able to relate the double refraction and the stresses producing it. He showed that when a glass was in a state of compression it behaved as an optically negative crystal, whilst if it were in a state of tension its behaviour was that of an optically positive crystal. The distribution of the double refraction in glass which had been rapidly cooled was examined by Macé de l'Epinay, who found that a glass plate so treated exhibited negative double refraction at the edges and positive in the middle. He also showed that a chilled glass rod was in a state of compression at the circumference and in a state of tension at the centre. He expressed the double refraction at a point in the specimen by the equation $y = A(e^{ax} + e^{-ax} + 2)$, A and a being constants and x the distance of the point from the centre. Czapski showed that there was an unstressed neutral zone between the region of compression and that of tension. Schott discovered that strain was slowly relieved even at 100°. Pockels first examined the variation of double refraction with composition (this Journal, ABS., 1918, **2**, Nos. 96, 97, 182, 264). In all previous investigations, however, insufficient data were available to yield any rule concerning the origin of the double refraction. Neither the manner in which it depended on the temperature from which the glass was cooled nor its variation with the viscosity was examined. Its extent depended on at least five factors, namely, (1) the coefficients of internal and external thermal conductivity, (2) the specific heat, (3) the coefficient of expansion, (4) the elasticity constants, (5) the viscosity. Three lines of attack on the complete solution of the problem were therefore planned : (1) to ascertain for several glasses, and for different values of τ, the magnitude of the double refraction produced by rapid, uniform cooling from a temperature τ to a temperature of 20°; (2) to investigate the manner in which the double refraction so produced depended on τ for different glasses; (3) to determine the relaxation time (see later) at various temperatures for a glass strained to a definite extent.

The pieces of glass examined were $4 \times 4 \times 24$ mm., the square ends being polished plane. Afterwards, pieces 4, 8, 16, 20, and 24 mm. long were used to study the variation of the double refraction

with the size.   Small cubes of 5 and 6 mm. edge were also employed
for this purpose. Many different glasses were examined, lead-
containing glasses, in particular, being studied in detail.   A mercury
arc was the source of light employed for the estimation of the
double refraction, the line $546 \cdot 1 \ \mu\mu$ being selected.   The double
refraction was expressed in terms of the path difference between
the two rays, this being measured by a Babinet's compensator.
The electric furnace used for heating the glasses, the method of
measuring the temperatures of the test-pieces, and the optical
apparatus were fully described.

The glasses used for the first test were O 2994, O 3453, O 3832,
O 3439, O 2122, U.V. 3199, O 203, O 2071, O 722, O 463, O 578,
O 3269, O 748, O 211, 1447^{III}, O 802, U.V. 3248, S 367, S 386,
S 389. On the average, the path difference was ascertained for
four values of τ for each glass.   Typical results were :

Glass.	τ.	Path difference $\times 10^6$.
O 3439	540·5	29·2
	506·0	16·0
	466·5	4·68
	403·7	0·56
U.V. 3199	579·9	29·7
	531·3	6·71
	490·7	1·52
	456·9	0·69
S 367	555·8	——
	521·5	19·1
	484·9	2·19
	451·5	0·49

For each glass the general equation $(\tau_0 - \tau)(S + S_0) = C$ was satisfied
where τ_0, S_0 and C were constants characteristic of the glass, and
S the path difference corresponding with the chilling temperature τ.
This equation was also obtained theoretically, subject to the con-
dition that the chilling temperature was well below the softening
point.   At higher temperatures, the formula should not hold, and
this was confirmed by experiments on glasses O 608, O 203, O 578,
O 748, O 802, and S 386.   It was found that when the glass was
chilled from temperatures above the softening point the path
difference was almost independent of τ.   Six lead-containing glasses
were examined each at ten temperatures, covering a wide range,
and the results further confirmed the conclusion that the hyper-
bolic law held for low and became invalid at higher temperatures.
The constants appropriate to these glasses were :—

Glass.	Per cent. PbO content.	τ_0.	S_0.	C.
O 198	70·0	469·4	−0·181	23·5
O 41	61·0	473·4	−0·480	58·3
O 102	50·5	494·2	−0·291	66·3
O 118	43·0	490·4	−0·205	73·8
O 340	33·5	485·06	−0·142	45·6
O 378	25·7	497·59	−0·146	45·0

Thus τ_0 appeared to reach a maximum with decreasing lead content but the variation was not very pronounced, while C and S_0 showed distinct maxima at 40 and 60 per cent., respectively. It was suggested that these maxima were due to the formation of new compounds between PbO and SiO_2 at these points. When curves were drawn showing the relation between C and the lead content and between S_0 and the lead content, and extrapolated for higher percentages of lead, both C and S_0 became zero for about 76 per cent. PbO, and then changed sign. This indicated that glasses containing 76 per cent. PbO should show no strain, and that with a further increase of lead there should be a positive double refraction, when examined by light of wave-length 546·1 μ. This confirmed in a remarkable manner Pockel's value of 75·7 per cent. (*loc. cit.*). Further confirmation was provided by results obtained with glass S 386 which contained 79 per cent. PbO. This glass exhibited positive double refraction, the values of the constants being $S_0 = +0·2178$, $\tau_0 = 456·6$, $C = -21·3$.

A yellow glass, 5899, which contained cadmium sulphide was unique in that whilst opposite edges of the test-pieces showed equal double refraction, that at adjacent edges was very different. With all the other glasses, the double refraction was the same at all the edges. It was suggested that the peculiarity of the glass might be due to the orientation of minute crystals of the colouring agent. The phenomenon was called polar double refraction.

Investigations with glasses O 118 and O 198 showed that when glass was strongly strained the strained decreased with lapse of time even at room temperature, but when the strain was slight there was a small but definite increase of strain. The former phenomenon had been theoretically explained by Maxwell, who connected the strain S_t after time t with the initial strain S_a by the relation $S_t = S_a e^{-t/T}$, T being a constant called the relaxation time. For strong strains in glasses O 118 and O 198, the values of T were $1·6 \times 10^7$ sec. and $2·5 \times 10^8$ sec., respectively. The relaxation time could be connected with the coefficient of viscosity of the glass and the elasticity constants and values for the former $3·2 \times 10^{10}$ and $5·0 \times 10^{11}$, respectively, were deduced. Possible explanations of the small increase of double refraction, when the strain was weak, were discussed, without any definite conclusion.

The experiments on the variation of the double refraction with the shape and size of the test-piece did not yield results to justify the suggestion of any rule.   J. R. C.

140. The Molecular Properties of Glass at Higher Temper-atures. H. SCHULZ (*Ber. Deutsch. Phys. Ges., Verh.*, 1918, **20**, 240).—The theoretical treatment of the problem of the distribution of stresses in a cooling solid was rendered difficult by the absence of data concerning the thermal constants at high temperatures. The case of glass was further complicated by the fact that it must be regarded as a solution of very low molecular mobility rather than as a solid. As the solubility depended to a large extent on the temperature, an alteration of the temperature should involve

a considerable change in the thermal constants.   At higher temperatures, chemical action might even occur without any visible change in the glass.   Theoretical considerations, therefore, were usually limited to a temperature range in which chemical changes probably would not take place.   For the upper limit of this region, Zschimmer had suggested the "cohesion temperature," or the temperature at which the adhesion and cohesion of two pieces of the same glass became equal, so that they adhered to one another. This was open to many objections, chiefly connected with the inevitable error which must obtain in its determination.   Another method of fixing the limit depended on the measurement of the strain produced by rapid cooling (see preceding abstract).   The constant τ_0 in the equation $(\tau_0 - \tau)(S + S_0) = C$ was taken to be the softening temperature of the glass.   This softening temperature and the cohesion temperature had been determined for the six lead-containing glasses and seven of the other glasses mentioned in the preceding abstract and were found to be very nearly equal.

Assuming that below this limiting temperature the deformation and relaxation time were functions of the temperature, the author developed a theory for the distribution of the strains.   If Einstein's law, that the greater the energy content of a body the greater its molecular mobility, applied to glass, the assumption was justified that the relaxation time, T, varied inversely as the energy content of the body.   An expression whereby T could be obtained from measurements of the absorption bands was developed from this assumption.   It was shown that for two glasses of similar composition, T would be shorter, and the plasticity greater, the nearer the ultra-violet absorption band was to the visible spectrum. Approximate values of T could be obtained from absorption measurements at the ordinary temperature.   J. R. C.

141. The Measurement of Dielectric Constants.   W. M. Thornton (*Proc. Roy. Soc.*, 1909, [*A*], **82**, 422).—Ellipsoids and cylinders were cut from the dielectric and suspended between flat plates connected to a transformer supplying a sinuous voltage of 1500 to 200 volts maximum, with a frequency of between 75 and 80.   The period of small swings of the suspended rod or ellipsoid, with and without the electric field, was observed, and the dielectric constant calculated from these measurements.   The derivation was given of the formula connecting the periods and the S.I.C.   It was stated that the method was susceptible of a high order of accuracy.

Crystalline quartz cut parallel and perpendicular to the optical axis and fused quartz were found to have dielectric constants 4·600, 4·5485 and 3·78, respectively.   Three glasses, which had been previously examined by Hopkinson, of densities 4·67, 4·1, and 3·3 were also tested.   The constants were 10·645, 8·52, and 6·98, respectively, these values agreeing very well with Hopkinson's. A curve was drawn showing the relation between the dielectric constant, k, and the density, d, of flint glasses, and from it was deduced the relation $k - 6·61 = 1·2965(d - 2·89)^2$.   The refractive index μ and k were connected by the equation $k - 6·61 = 95·6(\mu_F -$

$1.549)^2$, giving $\mu_F - 1.549 = 0.1155(d - 2.89)$.   Many other substances were also examined.

The glass or quartz ellipsoids and cylinders were suspended by forming a small drop of fused canada balsam on a quartz fibre, slightly warming the surface of the solid, and quickly melting the drop into contact with it by the approach of a hot rod.   Usually this had to be repeated many times before a perfect suspension was obtained.   J. R. C.

142. The Electrical Properties of Flint Glass.   G. L. ADDENBROKE (*Phil. Mag.*, 1923, **45**, 516).—The paper referred mainly to a flint glass of density 6·01, but one of density 4·85 was also examined.   The former could not be obtained in large sheets, so a method of mixtures was employed to find its dielectric constant. The capacity of an air condenser consisting of two metal plates, of area 250 sq. cm., placed from 2·5 mm. apart was calculated and also measured.   The difference between the two gave the " outside capacity " of the condenser.   The air condenser, being in the form of a box open at the top, was then filled with powdered glass, the volume of which was known.   Paraffin oil, of which the S.I.C. was known, was now poured into the box until it was full, after shaking to get rid of bubbles.   The capacity of the condenser was again measured, the true capacity of the mixture being equal to the measured capacity less the outside capacity of the condenser.   The dielectric constant of the mixture was then the ratio of this true capacity to the calculated air capacity.   The dielectric constant of the glass could be calculated from Thwing's formula

$$k_{\text{glass}} = \frac{(\text{Volume of mixture} \times k_{\text{mixture}})(\text{Volume paraffin} \times k_{\text{paraffin}}).}{\text{Volume of glass.}}$$

An alternating voltage of 110 volts at frequencies of 150 and 1200 was employed.

Thornton's curve (see preceding abstract) was reproduced and extended, it being shown that the values obtained, namely, $k = 11.2$ for the glass of density 4·85 and $k = 13.0$, for glass of density 6·01, lay on the curve, although Thornton's formula did not hold.   The approximate percentage composition of the heavier glass was $22SiO_2$, $78PbO$.   Its refractive index for the D-line was 1·9201 and the C—F dispersion 0·04381.   It softened and melted at a low red heat, without blackening.   Only one heavier glass was known, this being produced at the Smithsonian Institution, having a density of 6·33, and a percentage composition of $21.9SiO_2$, $78PbO$, and a trace of arsenic. $PbSiO_3$ was composed of $78.6PbO$ and $21.4SiO_2$ and so it was considered possible that these heavy glasses might consist of $PbSiO_3$ with dissolved silica.   The ratio of k to the square of the refractive index continually increased as the density of lead-containing glasses increased.

Frink had pointed out to the author that when a heavy glass crystallised out crystals of two different shapes could be observed, indicating the possibility of such glasses consisting of a mixture of two silicates.   J. R. C.

143. The Resistivity of Vitreous Materials. L. L. HOLLADAY (*J. Franklin Inst.*, 1923, **195**, 229).—Eleven specimens of glass had their electrical resistance determined at temperatures between 20° and 500°. For the temperature range 20—75°, the measurements were made with the current traversing the walls of the glass tube radially by sealing one end, filling the tube with some conducting liquid and immersing it in a bath of this same liquid. At higher temperatures, the determinations were made with the current passing longitudinally along the walls, connection being made either by electroplating the ends with a band of copper or by sealing wires into the ends. Glass tubes of about half an inch in diameter were employed.

The curve obtained when the logarithm of the resistance was plotted against the reciprocal of the absolute temperature was practically a straight line which, on projection, intersected the temperature axis close to the origin. The empirical formula

$$\log_e(R) - x\log_e(T) = \frac{Q}{T} - \log_e(P)$$

was found to satisfy the results for each specimen of glass, the constants P, Q, and x having the following values (T being the absolute temperature) :

<div align="center">Values of Constants.</div>

Type of glass.	For $x = +\frac{1}{2}$.		For $x = 0$	
	P.	Q.	P.	Q.
Hard glass (1)	453	11,630	9·1	11,280
Hard glass (2)	157	10,280	5·7	10,160
Light flint glass (3)	2,291	12,430	74·1	12,270
Light flint glass (5)	2,870	12,510	84·1	12,340
Light flint glass (7)	8,091	12,970	99·5	12,400
Light flint glass (9)	1,807	10,040	49	9,790
Lime glass (10)	1,145	9,370	23·7	9,050

The chemical composition of the glasses was not stated.

<div align="right">W. E. S. T.</div>

144. The Selection of Glass for the Manufacture of Ampoules. G. E. ÉWE (*J. Franklin Inst.*, 1920, **189**, 649).— Conformity to an " alkaloid alkalinity test " and a " spicule test " were regarded as imperative for a glass to be used for ampoules. The former required that a 1 per cent. solution of U.S.P. morphine sulphate, or a 0·2 per cent. solution of strychnine sulphate in normal saline solution must not develop crystals or become turbid or opalescent when sterilised under practical conditions in ampoules made from the glass, the ampoules having been treated with dilute hydrochloric acid and finally thoroughly washed free from the acid and dried before the alkaloidal solution was placed in them. In an extension of this test, the particular solution which the ampoules were destined to contain was used instead of the morphine or strychnine solutions. For the " spicule test," a 0·6 NaCl solution was placed in the ampoules, which were sealed and sterilised. The

solution was then examined under a magnifying glass for spicules or splinters of glass.

Five further tests, for comparative purposes, were also given. In a " phenolphthalein alkalinity test " the glass was washed, and treated with HCl. A sample of area 500 cm.² was then boiled in distilled water for sixteen hours. One c.c. of phenolphthalein solution was added to the water and titrated to neutrality, and the alkalinity reported as milligrams of NaOH per sq. dcm. The difference in the weights of the sample before and after boiling provided a " loss to water test." If a 2 per cent. aqueous solution of sodium carbonate was used instead of water, the differences between the weights were tabulated as a " vulnerability to alkaline fluids test." The other two tests were a " phenolphthalein " and a " phenol-sulphonephthalein alkalinity autoclave test." A few drops of the test solution were put in an ampoule and autoclaved at 12 lb. steam pressure for forty-five minutes. At the end of the time, the solution was examined for colour (acidity) and spicules.

Typical results obtained with ten glasses, offered for the manu-facture of ampoules, were tabulated. Glasses with a loss to water of more than 4 mg. per sq. dcm. were rejected. Two glasses which showed an alkalinity of 0·1 mg. in the phenolphthalein alkalinity test were passed. The results yielded by the application of the first three comparative tests to thirty-nine samples of glass tubing, bottles, and beakers were also tabulated. Losses up to 10 mg. per sq. dcm. in the second test and up to 57·5 mg. per sq. dcm. (the same glass) were noted.

The sources of the glasses tested were not indicated, nor were any compositions given.   J. R. C.

145. On the Constitution of the Silicates. G. TAMMANN (*Zeitsch. anorg. Chem.*, 1922, **125**, 301).—The atoms of solids were regarded as in vibration about fixed centres, but it was possible to have also an independent vibration of groups of atoms or molecules about the centre of gravity of the system. When this latter phenomenon occurred, the molecular heat of the substance did not coincide with the theoretical value, as calculated from the sum of the atomic heats. For a number of common silicates at normal temperatures, the calculated and observed values were practically identical, as shown in Table I, proving the absence of movement of molecular complexes in these silicates.

TABLE I

Molecular heat between 15° *and* 100°.

	Calculated.	Observed.	Observer.
Quartz	11·0	11·1	White
$CaSiO_3$	21·0	21·4	White
$PbSiO_3$	21·0	22·1	Schulz
$Na_2O,Al_2O_3,6SiO_2$	106·0	104·9	Joly
$K_2O,Al_2O_3,4SiO_2$	84·0	84·3	Joly
$Li_2O,Al_2O_3,4SiO_2$	84·0	80·8	Schulz

A distinction between complex silicates and carbon compounds was that the former were often largely dissociated when molten or in solution. Doelter obtained from fused *augite* crystallised *spinel*, *diopside*, and *quartz ;* from molten granite, *anorthite* and calcium orthosilicate; and from *albite*, a mixture of *nepheline* and *quartz*. In crystallising out silicates composed of K_2O, Al_2O_3 and SiO_2, or Na_2O, Al_2O_3, and SiO_2, it had been found that the substance obtained depended on the concentration of the various components in solution, indicating that the silicate molecules had no independent existence in solution. Lembergs, for instance, was able to change *analcim* into *leucite* by treating with potassium chloride solution. Constitutional formulæ for silicates had not, therefore, the meaning of those for carbon compounds ; and differences in chemical behaviour between crystallised silicates and silicate glasses of the same composition could not be so explained.   A. C.

146. Deformation Studies of Silicates and Aluminium Silicates of the Alkalis. B. A. RICE (*J. Amer. Cer. Soc.*, 1923, **6**, 525).—The investigation included studies of the two ternary systems K_2O, Al_2O_3, SiO_2, and Na_2O, Al_2O_3, SiO_2. The method of study was to make up cones (using dextrin as binder) of varying composition and observe their deformation behaviour when heated. Commercial raw materials were used rather than chemically pure, because the author desired to obtain practical results which could be applied commercially. The same general rate of heating was maintained as nearly as possible for each test, but it was found by trial that as much as one or even two hours' difference in the total time of heating did not affect their order of deformation, although the final temperature might vary.

Observation was confined to the order of deformation in establishing the eutectic, and although the temperatures were recorded for each test, it was not considered vital to attempt to measure accurately the temperature of deformation of the eutectic. At all times great care was taken to ensure uniform temperature throughout the furnace.

For the K_2O, SiO_2 series potassium nitrate and silica were mixed together in eight different proportions, ranging from 90 per cent. by weight of SiO_2 and 10 per cent. of K_2O to 80 per cent. of K_2O and 20 per cent. of SiO_2. The melting point of KNO_3 (337°) was too low to give results with cones made up from the raw materials; the nitre flowed away without reacting with the SiO_2 (and with Al_2O_3). Potassium carbonate gave difficulty in cone-making owing to its deliquescence; so frits of carbonate and silica and also of alumina were used to make the cones.

It was found that the members towards the high K_2O end of the triaxial (K_2O, Al_2O_3, SiO_2) were very deliquescent; they became very soft and gummy on standing a short time. Two deformation eutectics were noted on the straight line between K_2O and SiO_2, namely, K_2O, 55 per cent., and SiO_2, 45 per cent., with a deformation temperature of 780°, and K_2O, 17·5 per cent., and SiO_2, 82·5 per cent., with deformation temperature 870°. A ternary deformation

eutectic was found of the percentage composition K_2O, 17·41; Al_2O_3, 5·16; SiO_2, 77·43. This ternary eutectic had a much higher silica content and lower alumina content than any natural potassium aluminium silicate mineral known. The deformation temperature was low, 870°, bringing it close to that of a glass or enamel.

The Na_2O, Al_2O_3, SiO_2 system was tested in the same way as the potassium system, sodium carbonate being substituted for potassium carbonate in the frits. The members towards the high Na_2O corner with a Na_2O content above 50 per cent. had a strong or slag-like appearance, and were not glossy like those towards the high SiO_2 end. Two deformation eutectics were found on the straight line Na_2O, SiO_2, namely, Na_2O, 51·5 per cent., and SiO_2, 48·5 per cent., with a deformation temperature of 830°, and Na_2O, 18·4 per cent., and SiO_2, 81·6 per cent., with a deformation temperature of 860°. A ternary deformation eutectic was found of the percentage composition, Na_2O, 17·55; Al_2O_3, 5·33; SiO_2, 77·12. Its deformation temperature was 800°, and it had a lower alumina content than any natural sodium aluminium silicate mineral known. The composition of the ternary eutectic was practically the same in percentage by weight as that of the K_2O, Al_2O_3 and SiO_2 system. It might be said, consequently, that Na_2O and K_2O had the same fluxing value pound for pound when introduced in the form of carbonates.

The terms " eutectic " and " deformation eutectic " were used in this paper to designate those compositions which required the lowest temperature to complete the deformation when uniformly heated with other compositions in the manner indicated.

F. W. H.

147. The Fluorescence and Coloration of Glass produced by β-Rays. J. R. CLARKE (*Phil. Mag.*, 1923, 45, 735).—Three samples of glass, of approximate composition $6SiO_2, 1·5Na_2O, 0·5CaO$, $6SiO_2, 1·4Na_2O, 0·6CaO$, and $6SiO_2, 1·2Na_2O, 0·8CaO$ were kept in radium emanation until they were coloured deep brown and ceased to fluoresce. They were then heated at temperatures of 110°, 180°, 235°, and 350°, when fluorescence again occurred, lasting for a certain period which diminished from thirteen minutes at 110° to 0·5—0·75 minute (according to the glass) at 350°. The third of the three glasses fluoresced for fifteen hours when heated at 95°.

The relationship between the temperature and period of fluorescence indicated that between 500° and 600°, that is, probably in the neighbourhood of the annealing temperature, the glasses would be decolorised immediately. As both coloration and decoloration of the glasses were accompanied by fluorescence, the latter was probably due to change in the state of molecular aggregation of the glass. W. E. S. T.

148. The Melting of Potash Felspar. G. W. MOREY and N. L. BOWEN (*Amer. J. Sci.*, 1922, 4, 1).—A pure synthetic *orthoclase* was made by the crystallisation in a bomb with water-vapour

of glass of the composition $KAlSi_3O_8$. The artificial crystals were heated for a week at 1200°, the temperature ordinarily given as the melting point of *orthoclase*. The product had the appearance of a glass megascopically, but when examined under the microscope it was found to have a very fine cross-lining structure. At higher temperatures, this structure developed, showing skeleton crystals, widely extended and rectangular in a matrix of somewhat lower refractive index at 1250°; becoming more like rectangular crosses at 1300°; and finally, at 1400° or higher, forming typical *leucite* crystals.

Hence, 1200° was not the true melting point, but the temperature at which incongruent melting took place, giving *leucite* and liquid. The exact temperature at which this decomposition took place was ascertained as 1170°, and the temperature of the final disappearance of *leucite* was 1530°, giving an incongruent melting period of approximately 360°. Similar results were obtained, using *microcline* from N. Carolina, *sanidine* from Laacher See, and *adularia* from St. Gotthard, but in these cases the disappearance of *leucite* occurred at somewhat lower temperatures, namely, 1440° and 1460°, owing to the presence of impurities.   V. D.

149. The Thermochemistry of the Firing of Artificial Portland Cement. J. DAUTREBANDE (*Chal. et Ind.*, 1923, **4**, 221).—A study of the reactions involved in the production of the cement from clay or schist, and chalk or limestone. The temperature at which the process was completed was influenced by the chemical composition, grain size of the particles, humidity and homogeneity of the mixture. The most economic conditions held when the materials were ground to pass a mesh 200 to the sq. cm.; when the mixture was wet (37 per cent. water), and when the lime content was not excessive. The presence of oxides of iron and alumina facilitated the reaction between the clay and the limestone, whilst amorphous silica, or free quartz, retarded it. The carbon dioxide of the carbonates was expelled completely at a temperature of 900°, and the reactions were completed at 1550° in general.

V. D.

III.—Lamp-worked and General Scientific Apparatus.

150. A New Form of Melting-point Apparatus. H. A. BELL (*J. Ind. Eng. Chem.*, 1923, **15**, 375).—Novel features were the use of a water rheostat, *AB*, and duplication of the circulation

tubes of the sulphuric acid bath. The circulation was in the opposite direction to that in the ordinary Thiele form. The middle leg of the bath should be slightly larger in diameter than the two outer ones, for example, $\frac{3}{8}''$ tubing and $\frac{11}{32}''$. It was wound with 50 feet of No. 34, B. & S. gauge nichrome wire, C, the ends being connected to terminals, R, conveniently located on the outer legs. The rheostat was a glass tube 2 inches in diameter and 20 inches long, with adjustable electrodes, B, and was filled with salt solution, the strength of which, together with the distance between the two electrodes, formed the means of altering the resistance. The apparatus was stated to be simple in operation and to furnish accurate and consistent results.

FIG. 67.

M. P.
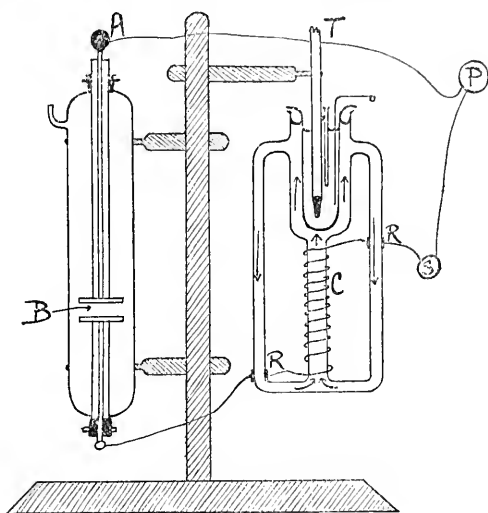
151. A New Form of Precision Hydrometer. C. W. FOULK (*J. Opt. Soc. Amer.*, 1923, **7**, 327).—The float, A, was entirely submerged in the liquid and was anchored by a fine chain, B, to the rod, C, which was capable of vertical movement. The chain hung in a catenary, being more or less supported by the float according as the density of the liquid increased or decreased. All the details were not yet available, but the apparatus had been proved twice as sensitive as the form in which the float was merely anchored to the bottom. An equation for determining the movement of the float for a given change in density was given. Results so calculated were within 3 per cent. of the actual values when checked by density determinations with an Ostwald-Sprengel pyknometer. Cotton thread could be used to lengthen the links of the chain without materially adding to their weight, thus increasing the sensitiveness of the apparatus. Several forms were described.

M. P.
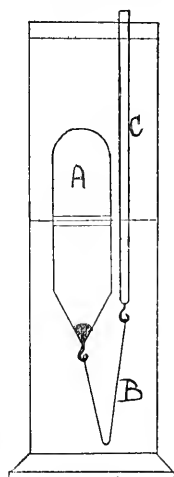
FIG. 68.

152. A Laboratory Fractionating Column. H. T. CLARKE and E. J. RAHRS (*J. Ind. Eng. Chem.*, 1923, **15**, 349).—The column is a Pyrex tube 90 cm. long, and 2 cm. internal diameter. Starting
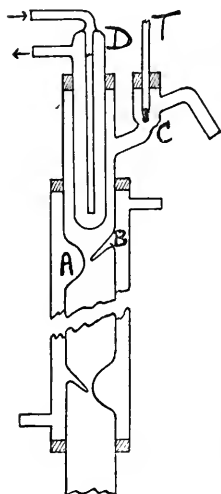
FIG. 69.

15 cm. from the top, a series of semi-bulbs, *A*, are sucked in each one as near its upper neighbour as possible and set at right angles to it. On the side immediately opposite each bulb, downward sloping points, *B*, are poked in with, say, a file tang, to within about 1 mm. of the convex surface. The series ends 10 cm. from the bottom of the tube. A side arm, *C*, 1·5 cm. in diameter, is sealed in 8 cm. from the top, and the delivery tube from this has a short upward bend before turning down to the condenser. This arm is best lagged with asbestos on its lower portion. A Pyrex tube, *D*, of construction shown, forms a stopper to the column and can be water-cooled and arranged at varying heights relative to the side arm opening, so that the condensed liquid returns from it to the flask at a rate ten to fifteen times as quickly as that at which it collects in the receiver. The jacket round the column serves to carry a current of cold air or water when dealing with liquids of low boiling point. When used to distil liquids under reduced pressure, the usual capillary tube should be omitted if possible, to avoid entrainment of vapours by the air so admitted.   M. P.

153. A New Absorption Bottle for Carbon Dioxide and Moisture. W. E. MORGAN (*J. Ind. Eng. Chem.*, 1923, **15**, 266).—
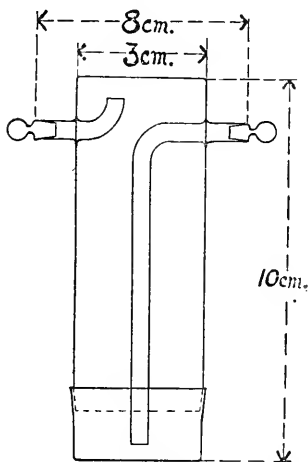
FIG. 70.

To charge, the bottle is stood on its flat top and the soda-lime introduced, then a plug of cotton wool or spacing disc of perforated rubber, followed by the calcium chloride and finally the ground cup base is replaced after greasing. The gas current enters at the top and leaves from the bottom. The weight, when two-thirds filled with moist soda-lime and one-third with calcium chloride, is in the neighbourhood of 80 gm. The advantages claimed are, lightness relative to the size of the chamber, ease of manufacture, convenience in filling together with complete accessibility when removing a caked spent charge, and, finally, durability under ordinary working conditions. It had been found entirely satisfactory for continuous

work necessitating the absorption of relatively large amounts of carbon dioxide. M. P.

154. A New Vessel for Electrometric Titration. W. T. BOVIE (*J. Amer. Chem. Soc.*, 1922, **44**, 2892).—The vessel, *A*, of about 150 c.c. capacity, was made of Pyrex glass, the lower end terminating in a solid glass rod which fitted loosely into a metal base, *B*. Four tubulures were provided, three as shown and a fourth closed at will with a rubber bung. This last served for the introduction of indicators or to provide a vent when the bubbling hydrogen electrode was used. The tubulures were so set as to bring the ends of the electrodes close together at the bottom of the vessel to allow of titrations being carried out with small volumes of liquid. The author claimed that the apparatus was specially suitable for class work. M. P.
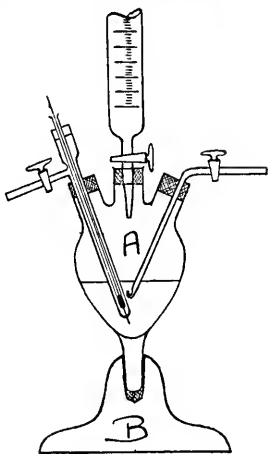
FIG. 71.

155. A Conductivity Cell. P. S. DANNER and J. H. HILDEBRAND (*J. Amer. Chem. Soc.*, 1922, **44**, 2827).—The usual form of concentric cell had the cylinders spaced by glass beads fused to their edges. This modification supported the cylinders on stout annealed platinum wires welded to the inner and outer cylinders at opposite sides and opposite ends. Adjacent to the lead from each electrode, a short stout piece of platinum wire was welded to the other and a strong glass sealing bead held the two correctly spaced apart. Long glass seals, *B*, with mercury seals, *C*, kept the apparatus gas-tight. The cylinders were of bright platinum foil 70 mm. by 13 and 16 mm. diameter, respectively. The apparatus was very satisfactory for work with small amounts of poorly conducting liquids, as its capacity was only about 17 c.c. and its constant was 0·00609. M. P.
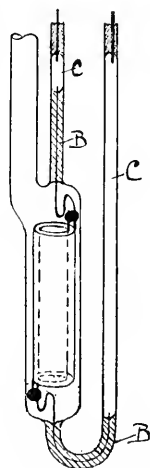
156. A New Method for the Control of Thermostats. D. J. BEAVER and J. J. BEAVER (*J. Ind. Eng. Chem.*, 1923, **15**, 359).—After reviewing critically previous methods of construction of thermoregulators with regard to the fouling of the mercury by arcing at the break, the authors described the method adopted by them in keeping a 12-litre bath at $25° \pm 0·001°$ for three months. In principle, a very

FIG. 72.

small current was used through the regulator to minimise the energy of the spark, and this current was amplified by a thermionic valve to control the heating current. The figure shows the arrangement

adopted for a 120 volt D.C. supply. R_1 and R_2 are rheostats of, approximately, 120 ohms resistance carrying 2 amperes, F is the filament, G the grid, and P the plate of the valve, R_3 and R_4 are 1 mg. ohm resistance units, C_1, C_2, and C_3 mica condensers, and A is a telegraph relay sufficiently robust to take 3 amperes when necessary.

For an alternating source of supply the apparatus would need to be modified by the elimination of the condenser C_1, and the use of the condenser C_3 of 1 microfarad capacity, in parallel with the windings of the relay.
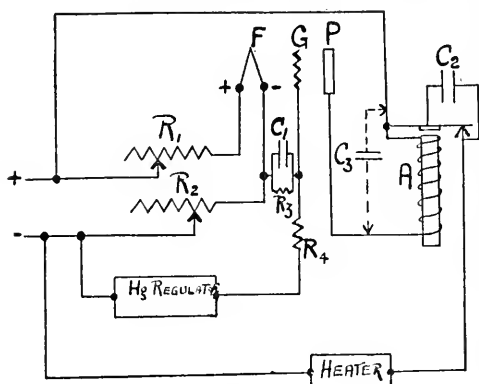
Fig. 73.

A monel metal tube filled with mercury was found very quick in its response to fairly large changes in room temperature. The difficulty of fastening a glass capillary to the end of the tube for the electrical contacts was surmounted by etching the glass, silvering, coppering, and soldering the copper to the monel metal. The whole was then heavily nickel-plated and the joint was found satisfactory.   Iron or nickel wire was better than the ordinary platinum, since neither of the former was wet by mercury and consequently the temperature of the " make " was the same as of the " break."   In the author's arrangement the regulator was so placed that the vibrations from the stirring motor of the thermostat set up periodic vibrations of the mercury surface, producing an oscillating contact as good as that obtained by mechanically oscillating the contact point.   M. P.

157. An Improved Optical Lever Manometer. E. K. CARVER (*J. Amer. Chem. Soc.*, 1923, **45**, 59).—The instrument was similar in principle to that previously described by Shrader and Ryder (this Journal, ABS., 1921, **5**, 16).   Since Rayleigh's tables (*Proc. Roy. Soc.*, 1915, **92**, [A], 184) showed that the maximum capillary depressions for mercury in tubes of diameters of 20, 24, 31, and 35 mm. were 0·026, 0·010, 0·0015, and 0·00059 mm., respectively, the float chamber, B, was made of a tube 44 mm. diameter, in order to leave a margin to allow for possible effects of the float, G. This was constructed of steel to eliminate inaccuracies arising from irregular wetting by the mercury, and of such a shape that it floated almost completely submerged. The instrument previously described was subject to fluctuations of zero due to slipping of the knife-edges in their slots.   In the present apparatus, the knife-edges were replaced by needle points, E, resting one in

a pit and the other in a slot on the arms of the stirrup, F.   Glass was found more satisfactory than steel for these bearings for the needle points.   When the parts were well made, the needle points would reseat themselves, after moving, to within 0·0001 mm. The glass window, C, was of Pyrex glass, which was optically polished to prevent distortion of the light reflected from the mirror, H, of 2 metre focal length, and was fused in place by heating the whole almost to softening and melting the edges together with an oxygen-fed flame.   The mirror was produced by coating a disc of glass with platinum spattered from a cathode in a discharge
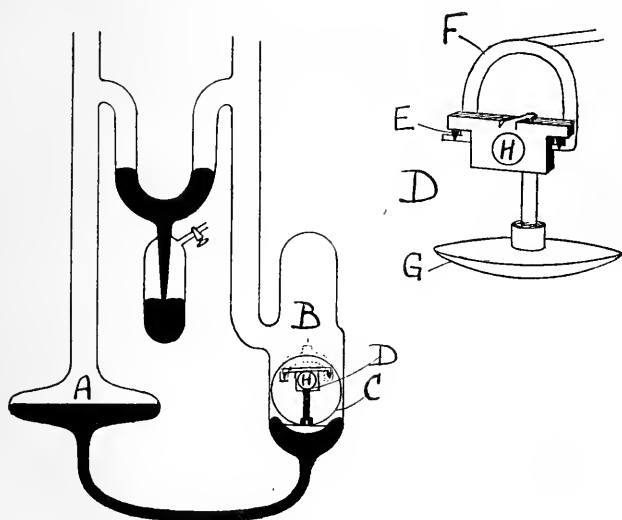
FIG. 74.

tube, since silver was attacked by the mercury and it was not feasible to employ a protective coating.   The instrument was mounted in plaster in an iron frame, a thin layer of litharge and glycerin being interposed between the plaster and glass to prevent cracking.

Whilst these changes increased the sensitiveness of the instrument to about 0·0001 mm., with an accuracy of 0·0002 mm. of mercury, readings needed careful watching, as the zero point would sometimes shift.   Minute ripples on the mercury surface caused much trouble and were difficult to eliminate until the instrument was placed on a slab suspended by rods from a rigid bracket on a concrete pillar.   M. P.

158. A Regulator Circuit for Thermostats.   A. T. LARSON (*J. Amer. Chem. Soc.*, 1922, **44**, 2893).—Many forms of regulator employed mercury contacts with the disadvantages of fouling and subsequent bad connections.   The author's device consisted in

using a low resistance relay of about 20 ohms in series with a high resistance, R, of 1500—1800 ohms connected to the supply circuit as in the diagram. The resistance, R, was set so that a current large enough to operate the relay was passed. The thermoregulator contacts being connected across the relay, the effect, when the contact due to the thermostat reaching the required temperature was made, was to short-circuit the relay and to dissipate the energy through the closed contact and the sparking was eliminated.
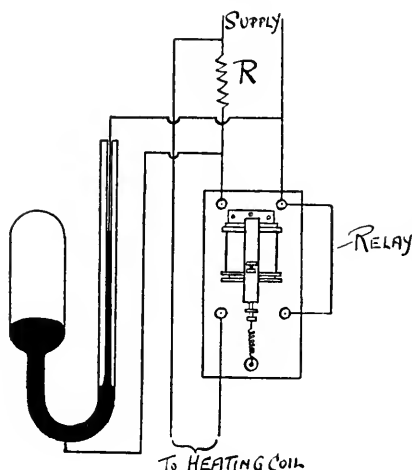
M. P.

FIG. 75.

159. A Method of Maintaining Small Objects at any Temperature between —180° and 20°. P. P. CIOFFI and L. S. TAYLOR (*J. Opt. Soc. Amer.*, 1922, **6**, 906).—The method was developed to prevent the condensation of ice from the atmosphere
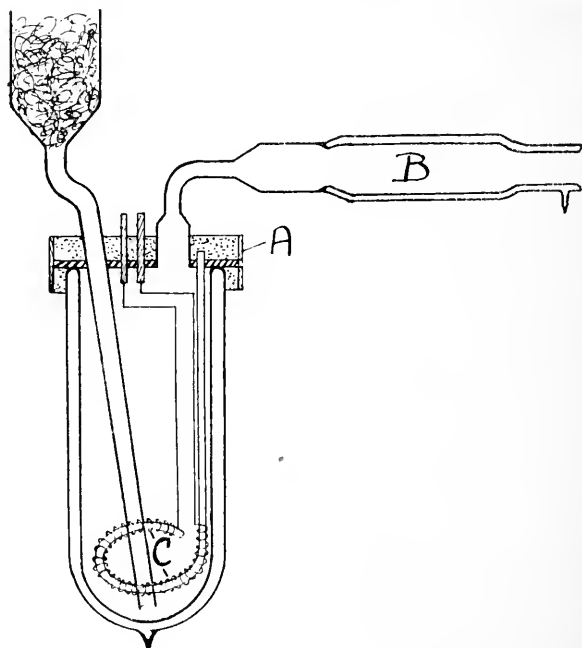
FIG. 76.

on objects under investigation, and consisted essentially in surrounding the object with a stream of cold, dry air obtained from the apparatus shown by the evaporation of liquid air. The coil, C, was electrically heated and the object placed in the vacuum-walled portion, B, of the delivery tube, which was susceptible of great variation in design to meet special requirements; for example, for visual observation or for X-ray work the sample could be placed just beyond the free end of the delivery tube and the cold air current drawn across by a strong suction applied to a tube about twice as wide as the delivery tube and fixed not more than a few diameters away from it. The cover, A, of the Dewar flask made an air-tight sealing wax joint, and filling of the flask was carried out through the funnel shown, which was provided with a plug of cotton wool for filtering out ice and solid carbon dioxide. Cleaning of the flask was found to be a frequent necessity, owing to the accumulation of frozen impurities masking the liquid air level.

M. P.

IV.—Decorated Glass.

160. Modern Table Decoration of Glass. K. GILLER (*Diamant*, 1923, **45**, 97).—In recent years decorated glass had found many applications, as in the lighting industry, where it was employed to beautify stand lamps. Other uses had been those of crystal glass for confectionery containers and cigar and cigarette stands. One type of decorated ware consisted of a cut-glass plate on which were grouped trees of various kinds, and in the centre an illuminated tree from which branched small detachable crystal baskets for containing almonds and raisins. Chains of cut glass beads formed the connections between the various objects. The colour variations of stained glasses had been used in the small-lighting industry and in the making of baskets of coloured stones and beads. Natural objects were also copied as far as possible, and a nice design was a grouping of violets and forget-me-nots in suitable glass vases. A further table ornament consisted of mirrored crystal-glass caskets with a precious-metal setting. In general, cut-glass ware was employed, pressed ware being seldom used.

A. C.

161. Engraving on Glass. (*Diamant*, 1923, **45**, 98).— Calcium fluoride mixed with a binding material such as printer's ink was applied to the glass by means of a rubber stamp. Sulphuric acid at a suitable temperature was employed to liberate hydrofluoric acid and so produce the etching, after which the glass was washed with a warm alkaline solution. A. C.

162. Coating Glass and Porcelain with Metals. (*Diamant,* 1923, **45**, 68, from *Moniteur de la Ceramique et de la Verrerie*).— The glass was first coated with a thin layer of gold chloride or platinic chloride in sulphuric ether, usually mixed with oil to give a sufficiently viscous liquid. Articles so coated were then introduced into ordinary electrolysing vessels. For a copper coating, the bath consisted of 2 parts of copper sulphate in 3 parts of distilled water. A silver bath was made from 12 parts of silver nitrate and 13 parts of potassium ferrocyanide in 300 parts of distilled water. For gilding, 7 parts of gold were dissolved in aqua regia, precipitated with ammonia, and the bath was made by treating the still moist precipitate with 8 to 9 parts of water. A mixture of 10 parts of gold and 1 part of silver solution gave " green " gold, whilst 10 parts of gold and 1 part of copper solution gave " red " gold.   A. C.

163. The Manufacture of Decorated Glass Plates. (*Diamant,* 1923, **45**, 98).—Methods which had previously been used to cover large plates of glass uniformly with a colour had not been successful. Where the coloured glass in the form of powder was spread over the casting table and the glass then poured on it and rolled, the powder was swept along during the rolling process and an unevenly coloured surface resulted. If a cement was employed to hold the powder in position on the casting table, the cement, in burning, formed unsightly seeds on the surface of the plate. A further method of first rolling the plate and then placing it on a casting table holding the powder and re-rolling, failed, since the surface of the plate was not sufficiently hot to ensure a true union. Finally, the method of preparing a cylinder on the pipe, rolling this on a layer of powdered glass, and afterwards working the cylinder in the glory hole, proved to be useless for making large sheets. The following method, however, could be successfully applied for this purpose. The glass was poured and rolled, and immediately a second roller, to which the powdered glass was attached by a cement, was passed over the upper surface of the plate. As a variation the powder was cemented to paper or other inflammable material and this was wrapped round the second roller. The material burned, and the ash was swept off by a broom before placing the plate in the lehr, whilst, when cold, the plate was placed in an acid bath.   A. C.

V.—Optics and Optical Instruments.

164. A Liquid Refractometer. S. NAKAMURA and A. MURA- MOTO (*Proc. Physico-mathematical Soc. Japan,* 1921—1922, **4**, 3).— The theory and description of a refractometer for a liquid were given. The principle of the instrument was to find the refractive index from the measurement of the focal length of a liquid lens,

the liquid being enclosed between a glass lens and a plane mirror. A brightly illuminated object was placed in front of the system and a real image reflected from the mirror was formed. This image was made to coincide with the object by using an auto-collimating occular.

Similar arrangements that have been described previously have not had simple reduction formulæ, the index of refraction of the glass lens entering into the calculation; but by the use of an equicurved concave-convex lens, the authors showed that the refractive index of the glass did not enter into the reduction formula. Thus, the method furnished an easy means of determining the refractive index. S. E.

165. The Parallelism of the Optical Axes of Binoculars. J. RAIBAUD (*Revue d'Optique*, 1922, **1**, 481).—Four arrangements whereby the parallelism could be tested were described. In the first, two parallel cylindrical beams were incident on the objectives and the light was examined, after transmission through the binoculars, by two parallel telescopes. In the second, light from a distant object was transmitted through the binoculars, which were focussed on infinity, and received by a camera. One clear image on the photographic plate denoted parallelism of the optical axes. The third arrangement was a modification of the second, two sources of light being employed and the beams made parallel by collimators. One collimator served this purpose in the fourth arrangement. J. R. C.

VI.—Illumination and Illuminating Ware.

166. Projection in Relief by Means of Polarised Light. PIERRE TOULON (*Bull. Soc. d'encouragement pour l'Ind. Nat.* 1923, **135**, 15).—The advantages of stereoscopic arrangements were pointed out, and also the difficulty of developing apparatus by means of which more than one spectator at a time could see the same thing. Previous devices were outlined, including the one in which complementary colours were used for the projection of the two images, and the observer used eye-glasses, one of which was tinted the same as one of the complementary colours, and the other glass was of the other colour, so that each eye received only one picture, and the net result was a stereoscopic effect. Such an arrangement precluded the full use of colours. There was also the cumbrous method by which two images were projected alongside on a screen, and the observers were supplied with adjustable stereoscopic eye-pieces with a screen to prevent cross-vision.

The author had used polarised light, polarised by reflection at 54° from the surface of a parallel series of eighteen or twenty sheets of glass, and it was arranged that two distinct beams giving vertically

polarised light and horizontally polarised light, respectively, impinged on the screen, giving two images simultaneously. The observer was supplied with viewing glasses which contained similar polarisers such that the left eye received horizontally polarised light and the right eye vertically polarised light. Thus each eye received one image, and one image only. For projection, it was essential to use the standard size 45×107 mm., or 6×13 cm., or 7×13 cm.; and, moreover, to see that the two pictures were simultaneously projected on to the screen. An ordinary white screen broke up the white, polarised light, but aluminium paint prevented this. The polariser had been placed between the luminous source and the plate, with 45×107 mm. plates between the condenser and the plate, whereas with 6×13 cm. or 7×13 cm., the polariser could not be placed after the condenser, although good results were obtained between the lenses of the condenser on an almost parallel beam.

To ensure clarity in projection, it was essential to place the source of light in a place easy to control and powerful enough to admit of projection in colour. A cylindrical metal filament lamp of 110 volts was used, with intensity between 300 and 600 c.p., and although coincidence of the images on the scale was not essential, the images should be about 5 cm. apart, that is, the distance of the eyes from each other.   W. S.

167. Preparation of Sodium Tungstate. BRITISH THOMSON-HOUSTON CO., LTD., London, and the GENERAL ELECTRIC CO., Schenectady, New York, U.S.A. (Brit. Pat., No. **189873**, September 8th, 1921).—For the production of sodium tungstate from tungsten
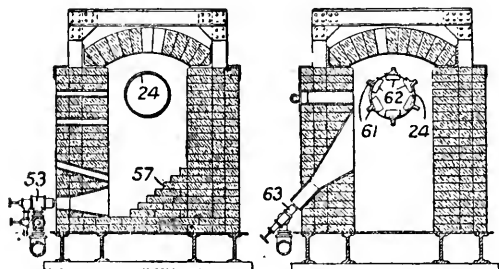
FIG. 77.

ores in a continuous manner, a powdered mixture of tungsten ore, sodium carbonate, and sodium nitrate from a hopper, 10, is fed by a gate, 19, to a band conveyer, 12, supported by a shelf, 18. The conveyer, 12, discharges the mixture into a hopper, 21, which discharges into a casing, 22, integral with a screw conveyer, 23, and containing vanes, 25, and a screw, 26. To the conveyer, 23, is attached a chain, 46, which prevents the material from balling when it falls into the inclined rotary tube, 24. The tube, 24, carries a hub, 43, which receives the conveyer, 23, and the space between the hub, 43, and the tube, 24, is packed with heat-insulating packing, 45. The tube, 24, is rotated by a motor, 39, and is set in a furnace divided into sections, 50, 51, 52, which are heated by gas-burners, 53, 54, 63. The floor of these chambers slopes upwards, as shown at 57, Fig. 77, the burners being set at one side. The chambers are heated so that the material is brought to and main-

tained in a semi-fluid state. Near the lower end of this tube are
openings, 60, with strengthening ribs, 61, between them on the
outside and plates, 62, between them on the inside to prevent the
charge from passing to the closed end of the tube. The material
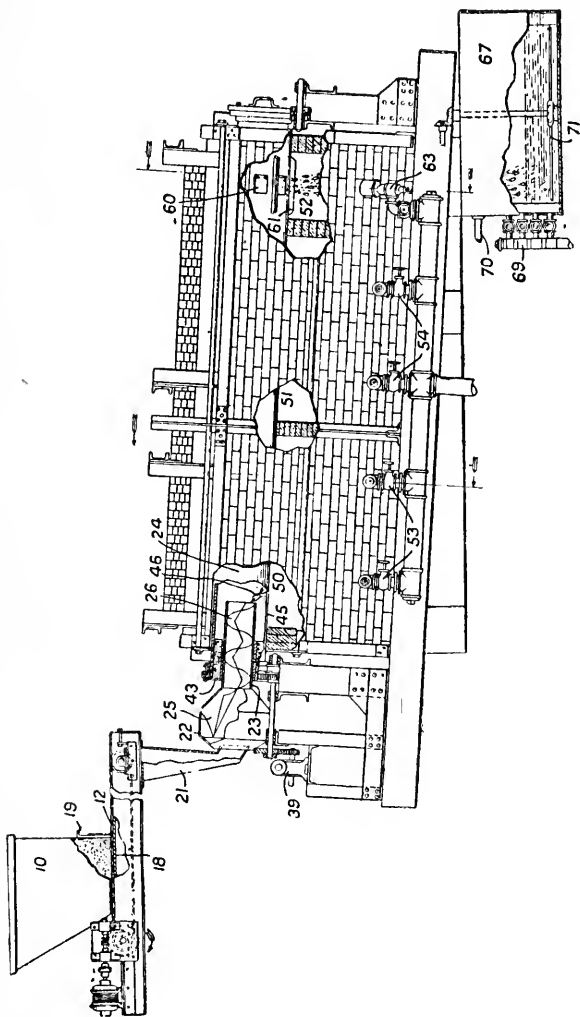
FIG. 78.

is prevented from clogging the discharge openings by the
flame from the burner, 63, which is directed on the tube. The
discharged material falls into a tank, 67, containing water, the
level of which is maintained by the outlet valves, 69, and inlet,
70. The solution is agitated by a stirrer, 71. Specifications
5457/80, 13323/87, and 9375/15 are referred to.   H. G. C.

VII.—Fuels, Refractories, and Furnaces.

168. Specific Heats of Gases. C. DE LA CONDAMINE (*Chal. et Ind.*, 1923, **4**, 64).—The specific heat of gases at constant pressure varied only slightly with the pressure. Thus for air over a temperature range of 27° to 77°, Lussana found a variation of only 0·0015 per 1 atmosphere change, whilst at 60° Holborn and Jakob gave a variation of 0·0003 per atmosphere. Lussana found for carbon dioxide a change of specific heat at constant pressure of only 0·002 per 1 atmosphere change, a variation of only 0·9 per cent. Theoretically, it could be shown that $\dfrac{dCp}{dp} = \dfrac{2aA}{RT^2}$, so that the variation of the specific heat with pressure would be much less at higher temperatures. A table and curves for finding the heat required to raise 1 kg. of steam, air, and other gases over varying temperature ranges at varying pressures were given. The following extract gives the heat required in large calories to raise the temperature of 1 kg. of steam from the saturation temperature to the temperatures indicated, under 1 atmosphere pressure absolute.

T.	99·1°	120°	140°	160°	180°	200°	220°	240°	260°
Cals	—	10·05	19·55	29·00	38·35	47·73	57·19	66·50	75·94
T.	280°	300°	320°	340°	360°	380°			
Cals	85·38	95·03	104·49	114·49	123·67	133·43.			

A. C.

169. The Gasification of Earthy Brown Coal with high Water Content. G. H. MEYER (*Sprechsaal*, 1922, **55**, 423).—The improvement in producer practice had rendered it possible to obtain good fuel gas from very inferior fuels. Whereas, twenty years ago, brown coal could only be used in the form of briquettes, it was now possible with modern plant to obtain an equally good gas from the raw fuel, although this contained 50 per cent. and more of moisture. The removal of the surplus steam in the gas, and efficient tar recovery, rendered the use of raw fuel economically possible. Compared with briquettes, much more raw fuel must be gasified in the producer to yield the same amount of gas, the proportion being from 3 : 2 to 2 : 1. For good producer work with raw brown coal, the grate must be so arranged that the fuel in the heating zone was well stirred up, so that the air dispersion was regular and burning through at the sides prevented. The author advocated the use of some steam in the blast, being of the opinion that the water content of the fuel was removed before arrival in the actual heating zone. The tar and water vapour were removed from the gas by an installation consisting of a pre-cooler, centrifugal washer, scrubber, and final cooler. The pre-cooler could be dispensed with if the gas left the producer at a temperature of less than 100°, as was frequently the case when very wet fuel was used. Practically all the steam and tar vapour were removed from the

gas, the removal of the steam increasing the calorific value of the gas to such an extent as more than to balance the loss due to tar removed and the sensible heat of the gas.

The advantages of steam and tar removal were (1) smaller gas mains required and no steam traps, therefore lower installation costs; (2) less attention required, the tar being collected at one spot and not throughout the system; (3) no stoppages, or freezing up of the pipes; (4) cleanliness in work; (5) the recovered tar, of good quality, commanded a good price.

The disadvantage was the greater power consumption necessary.

A comparison of the cost of production of heat from briquetted and raw brown coal when steam and tar were removed from the latter showed a considerable balance in favour of the raw fuel.

J. H. D.

170. How to Instal and Operate a Fuel Oil System. J. D. LALOR (*J. Amer. Cer. Soc.*, 1923, **6**, 448).—Tanks and pumps should be located in the lowest part of the property and the tanks at least six feet below the lowest pipe in any of the buildings. The pump suction should be three feet higher than the top of the tanks and the main oil line from the pump to the buildings should have a pitch of about half an inch in 10 feet. All the oil lines would then drain back automatically to the fuel tanks when the system was not in service. The tanks should be contained in a concrete pit to facilitate repair and avoid loss of oil.

When oil left the tank car it should be run by gravity or be pumped into an open strainer situated on top of the storage tank. In the case of heavy oils, it might be necessary to have a steam coil in the bottom of the strainer to warm the oil so that it would flow readily into the tank. Oil fuel tanks should be vented to permit the escape of air when being filled. The vent pipe should be at least 3 feet higher than the highest point for filling.

Heating was necessary in the tank, particularly in cold weather. There should be a sheet-iron casing like a barrel, openings cut in the side to allow the fuel oil to flow in around the coil, and a thermostatic control so that the oil was never heated to more than 110° F. Twenty-five gallons an hour could be heated to that temperature, on about one square foot of heating surface, with a pressure of about 5 lb. of steam.

The suction to the pump should be made in one piece, passing through the top of the tank, no joints or connections being within the tank itself in order to eliminate the possible leakage of air into the suction line. The bottom of that pipe should be about 6 inches above the bottom of the tank, the end plugged, and have perforations in the sides equal in area to the cross-sectional area of the pipe. This would prevent the possible lifting of any water which might collect in the tanks.

A fuel tank should be set 4 inches lower at one end, so that the water contained in the oil could settle to the lowest part and be pumped out from time to time as might be found necessary. A manual shut-off valve should be located outside the building

in the pit, covered with a plate indicating its use, and with a red light over it at night when the plant was in operation.

If air lines were under the floor, they should be attached to the burner with a goose-neck coming up so that no oil which accidentally leaked out of the burner could possibly pass into the air lines. No piping in any part of the system should be less than half an inch in diameter. The piping should never be galvanised and extra heavy cast-iron fittings should be used throughout. All joints should be either sweated or put together with freshly mixed litharge and glycerine of such a nature that the mixture would harden in twenty minutes when exposed to the atmosphere; any mixture requiring more than twenty minutes to harden should not be used.

Many drawings of fuel oil systems were given.   F. W. H.

171. A New Heating Gas for Chemical Industry. ANON. (*Chem. Zeitung*, 1923, **44**, 316).—Acetylene was a comparatively poor substitute for coal gas either for laboratory or works practice on account of " sooting "; but when generated under pressure as outlined, its use was rendered possible. For similar work to that required of town's gas, it was used at 200 to 500 mm. water gauge (in big plants up to 1000 mm. water pressure).

The " Weko " plant was described as being economical in operation, the generation of the gas being regulated by water pressure, avoiding in this way wastage which resulted from an unchecked gasification. The simplest type of burner was recommended, and in the laboratory the Bunsen burner was used.   W. S.

172. Producer Gas from Powdered Coal. R. T. HASLAM and L. HARRIS (*J. Ind. Eng. Chem.*, 1923, **15**, 355).—Experiments were conducted in a furnace capable of burning and reducing 12 lb. of coal per hour. In some runs, where the powdered coal travelled about 8 inches with the air stream before entering the furnace, half of the air was pre-heated. In other trials, when the coal was fed direct into the combustion zone, all the air was pre-heated.

The results of observations taken along the length of the furnace showed that the difficulties of the process were the production of a sufficiently high temperature in the reacting zone, and the maintenance of the necessary intimacy of mixing between the coal and the gas. Increase in the temperature of the incoming air gave better results, and 1000° was the best temperature to use. The maximum amount of CO obtained over a trustworthy run was 10·4 per cent.
    V. D.

173. Gasification of Lignite in Producers. C. ENGELHARD (*Zeitsch. angew. Chem.*, 1923, **11**, 98).—Shortage of coal had necessitated the use of inferior fuel in producers, but the producer had to be worked differently for the new fuel, since three times as much lignite was required to give the same heat as that obtained from the coal. In rotating grate producers, the quantity of lignite should not materially exceed the amount of coal which would be

present, but the air supply through the grate must be reduced, the advantage of a rotating grate being the prevention of stagnation and possible formation of a " bridge " which would hold up the fire. In contrast to the requirements of coal, lignite required a quiet fuel bed which moved from top to bottom with a slow steady speed, and a proportionately extended draught over the whole cross section of the producer, thus giving such a horizontal fire-zone as was compatible with a deep bed.

Keula and Muskau had a patented flat-grate producer with a very large capacity, as shown by the following table of results obtained :

Producer Diameter.	Capacity in tons per twenty-four hours.		
	Lignite briquettes.	Bohemian lignite.	German lignite.
2200 mm.	13·7 to 21·0 tons	15·5 to 22·8 tons	18·2 to 27·3 tons
2600 mm.	19·0 to 29·2 ,,	21·6 to 31·8 ,,	25·4 to 38·1 ,,
Rate of gasification in sq.m./ hour.	150 to 230 kg.	170 to 250 kg.	200 to 300 kg.

Illustrations were given showing, instead of the usual rotating grate and cap, a series of concentric ring-shaped bars with connecting straps, forming what was actually a table at the bottom of the producer, in which the spaces between the rings sloped downwards and outwards except just at the top where they were vertical, in order to admit vertical streams of primary air. Ash and clinker were ejected by a horizontal **S**-shaped rake, the vertical axle of which was introduced through the centre of the grate, so that the two arms of the rake, which were mussel-shaped, passed with their flat and open sides over the grate, thus shearing off any ash and clinker which might be formed. The usual water well below the grate served to cool the ash and admit water vapour into the producer itself. During operation, a fuel height of 800 to 1000 mm. was maintained with a depth of ash between 50 and 200 mm., and a fire-zone of 200 mm. It was pointed out that a low fuel bed was necessary in the gasification of lignite, as a high bed would give low temperatures at the top and condensation of the tar products would lead to the effective damping of the fire. W. S.

174. Analyses of Mine and Car Samples of Coal Collected in the Fiscal Years 1916 to 1919. A. C. FIELDNER, W. A. SELVIG, and J. W. PAUL (*Bureau of Mines Bulletin*, U.S.A., No. 193).—In an introductory portion the authors described the methods of coal sampling and analysis practised at the United States Bureau of Mines. Samples were received in a sealed 3-lb. can, the coal being first spread out to the depth of an inch on a weighed sheet metal pan and weighed. The pan was placed in a large oven at 30° to 35° through which a fan drove a current of warm air, and this drying was continued until successive weighings six to twelve hours apart gave a loss not exceeding 0·5 per cent. Then the sample was immediately powdered in a roll crusher to 10-mesh

and reduced with a riffle sampler to 500 gm., which fraction was
further pulverised in an Abbé ball mill to 60-mesh size.   A $\frac{1}{2}$-inch
screen served to detach the powdered coal from the pebbles, after
which the sample was further reduced in amount to about 60 gm.
by successive halvings in a small riffle sampler.   The final sample
was put through a 60-mesh sieve, and transferred to a 4 oz. wide-
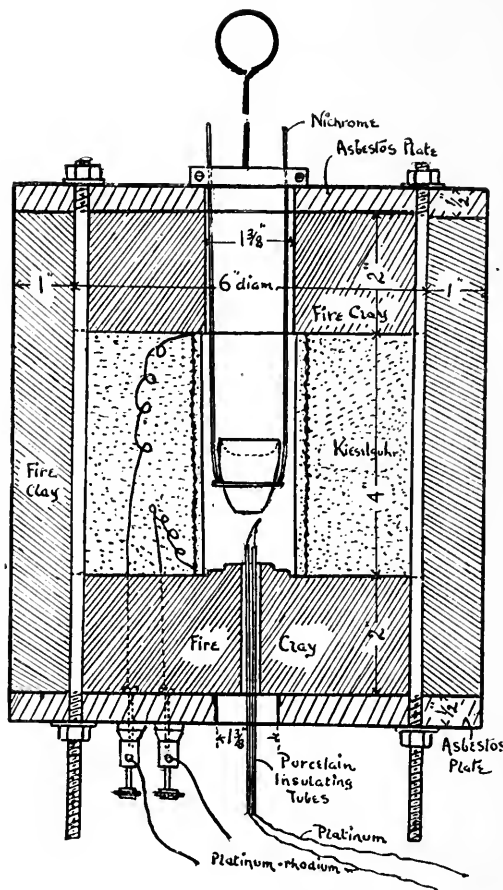
FIG. 79.

mouth bottle, which was closed with a well-fitting rubber stopper.
This air-dried sample was used in all analytical determinations.
For estimating residual moisture, a gram of the sample was dried
in a porcelain capsule of $1\frac{3}{4}$ inches diameter and $\frac{7}{8}$ inches deep for
an hour at 105° in a constant temperature oven through which
passed a current of dry, preheated air.   Ash was determined on
the same sample by placing in a porcelain capsule and gradually

heating from the cold in a muffle until the temperature was approximately 750°. The ignition was continued with occasional stirring until all particles of carbon had disappeared, and was then repeated until the weight was constant. For determining volatile matter, a 1 gm. sample was weighed into a bright, well-burnished, 10 c.c. platinum crucible, of height $1\frac{3}{16}$ inches, diameter of base $\frac{9}{16}$ inches, diameter of top 1 inch, with a close-fitting capsule cover. The crucible was heated for exactly seven minutes in a specially designed vertical electric furnace (Fig. 79) to a temperature of 950°.

A. C.

175. The Alumina-content and Fusibility of Clays. (*Sprechsaal*, 1922, **55**, 431).—The authors discussed the question as to whether the alumina content of a clay was a measure of its refractoriness and arrived at a negative decision. The fusion points of more than one hundred clays were compared with their alumina contents and very divergent results were obtained. Thus, in ten samples of clays, each with a fusion point of 1770°, the alumina content varied from 20 to 33·6 per cent. One sample with a fusion point of 1430° contained 28·4 per cent. of alumina. Conversely, eight samples, each containing 23 per cent. of alumina, had fusion points varying from 1300° to 1790°. The authors emphasised the fact that the refractoriness of a clay cannot be judged from its chemical composition alone and must be measured by an actual fusion test.   J. H. D.

176. A Noteworthy Property of Clay. M. A. RAKUSIN, (*Chem. Zeitung*, 1923, **20**, 115).—It was pointed out that ordinary clay (especially when fired) possessed absorbent properties similar to those of kaolin. Thus a deep brownish-red solution of 1 per cent. petroleum in benzine became decolorised with 5 per cent. burnt clay in twenty-four hours; the same result was obtained with 8 per cent. air-dried clay prepared by drying to constant weight in a desiccator. If experiments were made from a supply of such clay stored in a well-corked flask, good comparable results were obtained. If different media containing Bengal indigo were decolorised in this way, the filtrate from the aromatic hydrocarbons (benzol, toluol, xylol) was yellow, whereas the filtrate from the petroleum hydrocarbons (benzine, kerosine, vaseline) was colourless. Evidently the aromatic hydrocarbons had extracted an oil which was insoluble in the petroleum hydrocarbons, the origin of which was traced to the decaying or pugging process of the clay preparation.   W. S.

177. The Manufacture of Glass Pots. (*Diamant*, 1923, **45**, 114).—A special method stated to be employed in Bavaria. Clay and grog were mixed to a suitable slip with water, and, by a mechanical press forced through tubes into the completely closed mould. In the mould was a lining of porous material (felt, linen, etc.) backed by the mould itself, which was provided with many small channels,

communicating by cross channels and slits with the outside, whereby the extruded water could pass away.   By maintaining the pressure, a compact, fairly dry mass was finally obtained, at which stage the mould (specially constructed to allow of this) was removed.   A. C.
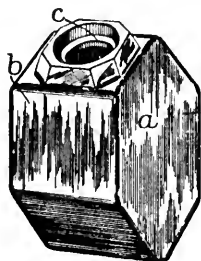
Fig. 80.

178. Melting-pots for Glass, etc. W. H. SQUIRES, Amblecote, Stourbridge, Worcester shire (*Brit. Pat.*, No. **191301**, February 8th, 1922).—A clay or like refractory melting-pot for glass or other substances has circular, polygonal, or elliptical walls, *a*, which may be plane, or convex, united by a circumferential portion, *b*, a part of which rests on the furnace floor. A mouthpiece, *c*, is provided.
H. G. C.

179. A Study of the Slag Test. R. M. HOWE (J. *Amer. Cer. Soc.*, 1923, **6**, 466).—Two distinct types of slag tests were investigated. In one case the penetration of the slag was measured by means of a planimeter; in the other its solvent action was determined by studying its effect upon the fusion points of firebricks. The penetration of slags of different compositions was studied on three types of firebrick by placing the finely ground slag in cavities of the brick and heating.

The slag penetration was practically complete in less than two hours, and the results of the tests were not influenced to an appreciable extent by increasing the time of test or the amount of slag.   The results were affected considerably by the furnace atmosphere.   Generally speaking, penetration increased with an increase of temperature, although the increases with different slags and bricks were not relatively the same.   The slag penetrations at 1150°, 1250°, 1350°, and 1450° were determined on the three brands of firebrick, and were not in the same ratio at the different temperatures, so that to compare different bricks it was necessary to test them at a temperature approximating to that of the furnace in which the slags were melted.

The results were controlled to a very large extent by the density of the brick, being low with the steam-pressed and high with the hand-made product.   The penetration test made no distinction between mechanical penetration and chemical action, so that open and porous bricks would always show a large penetration, although they might be unaffected by the solvent action of the slag, whilst very dense bricks might give a low penetration, although they were seriously attacked.

It was impossible to discover any relationship between the laboratory and practical results.   A test, which gave results agreeing with practice, was made by mixing samples of each brick, ground to pass a 60-mesh sieve, with different percentages of slag. The mixings were made into cones and their fusibilities determined.   The relative fusion points of the brick–slag mixtures

should indicate the resistance of the brick towards the action of the slag, and for two samples tested the laboratory and the practical results were in agreement. F. W. H.

180. Refractories for Oil-burning Furnaces. (A DISCUS-SION) (*J. Amer. Cer. Soc. Bull.*, 1923, **2**, 19).—A. F. Greaves-Walker had described the effect of oil on refractories as that of rotting, due to the impingement of the oil upon the surface of the brick and the minute explosions which took place. R. L. Frink stated that apparently the Greaves-Walker theory was that because of these minute explosions and the extremely high temperature occasioned at the instant of the explosion, there was a disintegration of the surface. He (Frink) was somewhat inclined to this theory, but not to the view that there was a sintering or actual fusion of the brick at the instant of these explosions and a subsequent disintegration because of continued or repeated explosions.

R. L. Frink presented another theory which assumed that in the presence of water vapour at high temperature silica was acted on and removed as a hydride. F. W. H.

181. Composition and Properties of Diaspore, Bauxite, and Gibbsite. R. M. HOWE and R. F. FERGUSON (*J. Amer. Cer. Soc.*, 1923, **6**, 496).—Highly aluminous bricks might be made from *diaspore, bauxite,* or *gibbsite. Diaspore* was the monohydrated, *gibbsite* the trihydrated alumina, and *bauxite* a mixture of the two. These materials varied considerably in chemical composition except as regards magnesia, the alkalis and titania; the samples used in the authors' experiments gave the following ranges of composition :

Ignition......	9·88—28·08 per cent.		Titania	2·09—3·85 per cent.	
Silica	1·36—20·50 ,, ,,		Lime	0·22—3·17 ,, ,,	
Alumina ...	52·48—73·70 ,, ,,		Magnesia	0·16—0·79 ,, ,,	
Ferric oxide.	0·47—23·55 ,, ,,		Alkalis	0·37—1·34 ,, ,,	

Their fusion points (cones 34 to 42) were lowered most by lime and least by ferric oxide and silica. The burning shrinkages (0·0 per cent. by volume at 1050° to 55·2 per cent. at 1500°) of the minerals high in silica were lowest, whilst those high in ferric oxide shrunk most. *Gibbsite* had a higher burning shrinkage than *diaspore.*
F. W. H.

182. Refractory Compositions containing Thoria and Ceria. T. TERRELL and MONARCH MANTLES, LTD., both in London (Brit. Pat., No. **189492**, August 2nd, 1921).—In a process for the manufacture of a refractory or light-giving body of thoria and ceria wherein a soluble salt of thorium is used as the binding agent, a mixture of thoria, a cerium salt, and the thorium salt is powdered to a degree of fineness wherein the particles are not smaller than 0·01 mm. and the proportion of the thorium salt to the whole mass is substantially 20 per cent. In one example of carrying out the process, a mixture of 100 parts by·weight of thoria, preferably

obtained from the ash of incandescent mantles, 30 parts of thorium nitrate, a small quantity of cerium nitrate, and about 1 part of magnesium or calcium nitrate or other hardening earths, is ground, converted into a thick paste by means of a small quantity of alcohol or other volatile liquid, moulded, dried, and ignited.   The powdered mixture may be modified by the addition of up to 30 parts of powdered carbon.   The powdered mixture may be suspended in collodion, nitrocellulose, or the like, and dried in sheet form for use as a gas mantle or squirted in the form of threads, which can be knitted or woven to form a gas mantle and then ignited.   The mixture may be made up in a solid form as pastilles for oxy-acetylene lamps or for use as a furnace lining or as crucibles.   H. G. C.

183. Refractory Compositions.   E. D. Frohman, Pittsburgh, U.S.A. (Brit. Pat., No. **186968**, June 10th, 1921).—A refractory composition consists of finely divided fireclay, a siliceous refractory substance such as ganister or asbestos, and a vegetable substance which acquires binding properties when moistened with water, such as sulphite pitch (a by-product from the manufacture of sulphite pulp), dextrin, or gum arabic.   The composition is mixed with water when required for use.   H. G. C.

184. A Device for Tapping Tank Furnaces.   W. R. Smith (U.S.A. Pat., No. **1439198**, December 19th, 1922.   Filed January 28, 1920, No. 354618).—A tap for enabling molten metal to be drawn off from a tank consists of a cylindical body of refractory material which is inserted into the wall of the tank and is provided with a plug of fusible material adapted to be melted out when required.
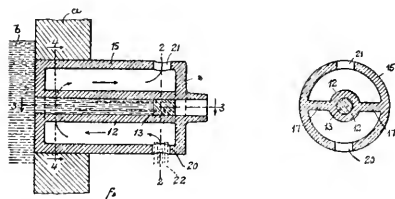
Fig. 81.

The device consists of an outer tube, 15, inserted in the wall, a, of the tank below the surface of the metal, b, and an inner tube, 12, through which the metal is withdrawn. Holes, 20, 21, are formed in the outer tube, and baffles, 17, unite both tubes.

A plug, 13, of fusible material, such as glass, normally prevents the metal from flowing out of the tube, 12.   A Bunsen burner, 22, is inserted in the hole, 20, when tapping is to take place, and melts the plug, 13.   The products of combustion from the burner pass around the end of the baffles, as shown by the arrows, and escape through the hole, 21.   G. D.

185. Improved Method for Cooling Tank Furnaces.   C. S. Stafford (U.S.A. Pat., No. **1443767**, January 30th, 1923.   Filed March 28th, 1922, No. 547475). — See this Journal, Abs., 1923, **7**, No. 76 (p. 42).   G. D.

186. A Tungsten Furnace for Experiments on Dissociation and Ionisation. K. T. COMPTON (*J. Opt. Soc. Amer.*, 1922, **6**, 910).—A piece of tungsten sheet of the necessary dimensions was bent up in the form of a cylinder and the ends were held between steel rings, *A*, and the split steel blocks, *B*, mounted on water-cooled brass tubes, *C*, turned from the solid and insulated by short glass tubes, *D*. The cylinder itself was strengthened at intervals along its length by encircling loops of fine tungsten wire drawn sufficiently tight to prevent bulging along the line of the seam. The central electrode, *E*, was a straight piece of 20-mil tungsten wire welded
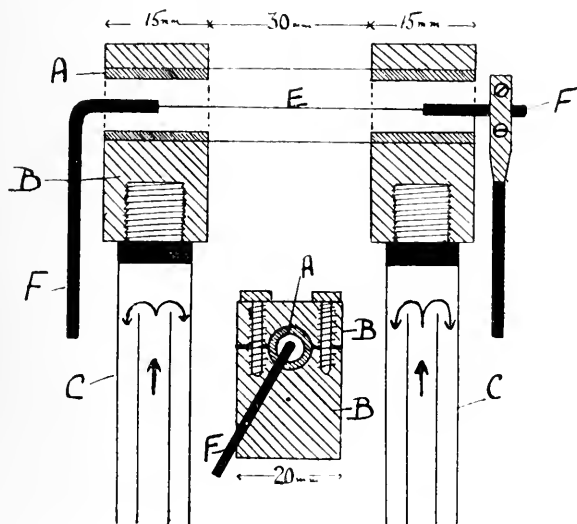
FIG. 82.

to heavy molybdenum leads, *F*, so clamped as to keep the wire in tension to prevent sagging when hot. The length of the central wire could be adjusted to give equipotential drops along both wire and tube. Molybdenum blocks would have been preferable to the steel ones used. The furnace shown needed 200 amperes, with a potential drop of six volts to reach its melting point, and at 100 amperes it reached a good white heat. Storage batteries were used, but, provided due regard were paid to ensuring that the currents in furnace and filament were in phase, it should be possible to use a transformer. M. P.

187. Heat Utilisation by Recuperation in Ceramic Furnaces. C. LOESER (*Ker. Rundschau*, 1922, **30**, 489, 499, 508).—The construction of the recuperators must be such that the exit gases and the secondary air acted on each other as long as possible. The recuperator walls must be as thin as consistent with mechanical strength. Multiple walls were superior to single walls. Correct

regulation of the gas supply and air supply was necessary. Regulation of the air supply was quite easy with recuperators. Regulation of combustion by analyses of waste gases was recommended. The correct control of the secondary air was impossible unless a gas supply of uniform quality and quantity was maintained. Recuperators must be so built that excessive heat loss to the ground and between them and the furnace was avoided. Excessive heat loss between the gas producer and the furnace must also be avoided.

Coke gas producers gave a uniform quality of gas. Coal gas required a great quantity of air for combustion, and therefore waste heat could be recovered relatively easily, but producer gas needed little air, and recuperation was therefore of little use. Correct regulation of the air supply was difficult with producers that were fed intermittently, owing to the variation in the amount of distillation products present in the gas. Producer gas was only employed with advantage in continuous furnaces. It was assumed that the amount of heat recoverable was greater than that lost during gasification, which, according to the author, amounted to about 25—33 per cent. of the total heat available in the original solid fuel.

In a semi-gas furnace the fuel bed was so deep that insufficient air could pass through in order to burn all the fuel to CO_2 and H_2O. Less secondary air was needed than with producer gas. The semi-gas producer became much hotter than the full-gas producer.

In general, recuperation was advantageous when by its employment the maximum temperature attainable could be raised and the durability of the finished ware increased, for example, furnaces for firing Dinas brick and magnesia brick. Recuperation was advantageous when burning porcelain, stoneware, terra-cotta, and pottery.

Sharp-pointed flames must be avoided. The more that semi-gas firing approached full-gas firing, the more easily could low-grade fuel such as lignite be employed.   H. W. H.

VIII. Chemical Analysis.

188. Quantitative Determination of Slight Quantities of Sulphate. H. J. HAMBURGER (*Proc. K. Akad. Weten. Amst.*, 1916, **19**, 115).—In order to have a method of determining the sulphate and comparing with macro- and micro-gravimetric analyses, the principle was used whereby the precipitate ($BaSO_4$) was centrifuged in a calibrated capillary tube until the volume was constant and could be read off, comparison being made with a standard sulphate solution. The following quantities of reagent were always used : 2·5 c.c. HCl (1 : 1) added to 5 c.c. of the sulphate solution, and to this mixture 5 c.c. of a 2·44 per cent. solution of $CaCl_2,2H_2O$

to which 3 to 5 drops of acetone had been added. The presence of sodium, potassium, calcium, magnesium, chlorine, or phosphate did not affect the result, which was obtained on the principle that an n-fold quantity of SO_4 gave an n-fold volume of $BaSO_4$.

W. S.

189. Analysis of Fluorspar. C. E. GIFFORD (*J. Ind. Eng. Chem.*, 1923, **15**, 526).—One gm. of the finely powdered sample was placed in a small Erlenmeyer flask, 10 c.c. of a 10 per cent. solution of acetic acid were added, and the mixture was heated on a water-bath for one hour, a short-stemmed funnel being placed in the mouth of the flask. Silica and the fluorides were only slightly affected, but the carbonates of calcium and magnesium, and some of the oxides of iron and aluminium, were decomposed, passing into solution as acetates. After filtering through an ashless paper, and washing thoroughly with warm water, the residue was reserved, and the filtrate and washings were acidified with sulphuric acid. This solution was evaporated, the calcium fluoride being converted into sulphate. After taking up the mass in a small amount of hydro-chloric acid, the iron, aluminium, calcium, and magnesium were determined in the solution, in the usual way. From the lime content, 0·0011 gm. was subtracted, the equivalent of the calcium fluoride dissolved. The calcium and magnesium were calculated as carbonates. Any lead present was removed as sulphide previous to the precipitation of the iron and aluminium.

The residue from the acetic acid treatment was ignited and weighed. Two evaporations with hydrofluoric acid followed, and the final residue was heated to dull redness, cooled, and weighed. The loss in weight gave the silica content.

This residue was treated with 5 c.c. of sulphuric acid, evaporated to dryness, and heated to redness, the addition and evaporation being repeated to ensure the complete conversion of all the fluoride to sulphate. Great care was necessary to prevent loss by spitting. The cool crucible and sulphates were placed in a 200 c.c. beaker, and boiled in water acidified with hydrochloric acid, containing 0·5 per cent. sulphuric acid to effect the solution of the sulphates. Any insoluble indicated the presence of barium, and was filtered off, washed, ignited, and weighed as barium sulphate. This was then treated with more sulphuric acid; any change in weight on ignition showed that the conversion of the calcium fluoride to sulphate had been incomplete. The filtrate was neutralised with ammonia, acidified with 5 c.c. of hydrochloric acid, and hydrogen sulphide was passed. Any lead sulphide was filtered off and determined in any convenient manner. The filtrate was boiled to expel H_2S, oxidised with potassium chlorate, and iron and aluminium oxides were determined. Any zinc was separated by means of H_2S, then the calcium and magnesium were determined in turn and calculated as fluorides. To the lime obtained thus, 0·0011 gm. was added; previously this had been subtracted in the determination of the calcium carbonate. Bulking to a known volume, and using an aliquot part for the estimation of the calcium, was recommended.

Any iron, aluminium, zinc, and lead compounds found in the first section of the analysis were added to those obtained in the second portion. Sulphur was determined in the usual manner, observing precautions given by Martin (*J. Ind. Eng. Chem.*, 1909, **1**, 461).

This method could be used for complete analysis of fluorspars, and had given very satisfactory results.   V. D.

IX.—Machinery for the Working of Glass.

190. Automatic Bottle-blowing Machine. Soc. ANON. D'ETUDES ET DE CONSTRUCTIONS D'APPAREILS MÉCANIQUES POUR LA VERRERIE, Paris, assignors to the WILZIN AUTOMATIC BOTTLE MAKING MACHINE CO., LTD., London (Brit. Pat., No. **191012**, December 7th, 1922. Not yet accepted).—A machine for blowing glassware, particularly bottles, has means for filling the parison mould by suction and also for connecting the suction apparatus with the joint formed by and between the contacting faces of the sections of the parison mould. The machine comprises a parison mould, 18, Fig. 83, formed in two parts which open and close about a spindle, 25, a ring mould, 60, to support the parison without movement during the substitution of the finishing mould, 19, for the parison mould, and a controller, 12, for regulating the suction and the supply of compressed air for blowing. The frame of the machine consists of a table, 1, and two standards, 2, joined by a crosspiece, 3. The mould supports are secured to the standards, the height being adjustable by nuts, 20, and an eccentric sleeve surrounding each standard enables each mould to be adjusted horizontally in relation to the axis of the ring mould. A shaft, 4, mounted on the table, has a double arm, 6, which opens valves, 7, 8, 9, when the shaft is rocked by pedals, 16, 16a, and puts the controller and a cylinder, 14, in communication with the suction pump or the supply of compressed air. The controller, 12, consists of a casing containing a disc perforated with a ring of holes of different diameters, one of the holes being brought into coincidence with a supply pipe when the plate is rotated, the size of the hole regulating the suction or compression which is applied to the ring mould. V-shaped members, 29, pivoted on the table and connected to the mould by links, enable the operator to open or close the moulds. The ring mould, 60, is mounted below the cylinder, 14, the interior of which is connected to the valve, 9, by a pipe, 13, and to the controller by a pipe, 46. Passages, 38, regulated by cocks, 39, connect the interior of the cylinder with ducts, 64, formed in the ring mould and grooves, 68, formed in the contacting faces of the parts of the parison mould. Thus, when suction is applied

to the cylinder, air is exhausted from the grooves, 68, and tight contact is secured between the halves of the parison mould, so that joint marks on the parison are avoided. The plunger, 43, that forms the initial cavity in the neck of the parison is mounted on the lower end of a rod, 42, which slides through a piston, 48, pressed upwards by a spring, 49. In operation, the ring and parison moulds are closed and a ladle full of metal is placed over the lower
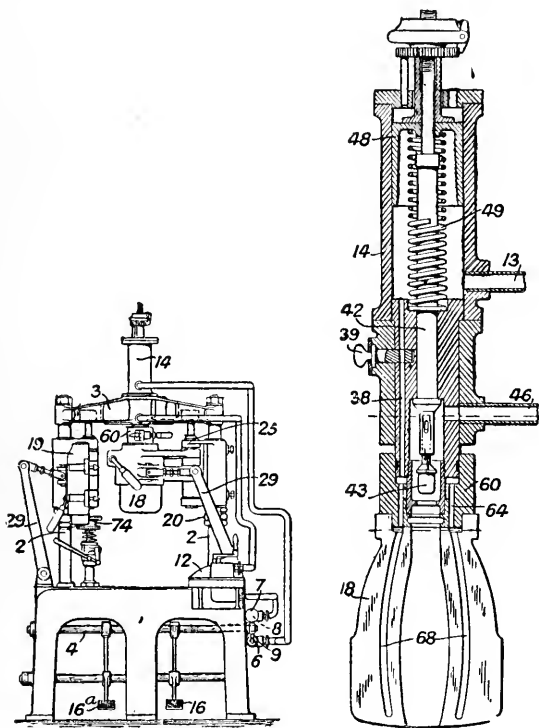
FIG. 83.

end of the parison mould. Suction is then applied to the cylinder, 14, and causes the piston, 48, to move downwards to bring the plunger, 43, into the ring mould. Movement of the controller then exhausts air from the ring mould through the pipe, 46, thus causing the metal to be sucked from the ladle into the mould. After removal of the ladle, the controller and the pedals are operated to stop the suction, the parison mould is opened, and the finishing mould, 19, and the bottom mould, 74, are moved to enclose the parison. Further operation of the pedals and the controller admits compressed air to the ring mould to blow the parison to the final shape.   H. G. C.

191. A Take-out Mechanism for Glass-blowing Machines.
O. Y. IMRAY, London, and the OBEAR-NESTER GLASS CO., St. Louis,
U.S.A. (Brit. Pat., No. **190224**, September 12th, 1921).—A pneu-
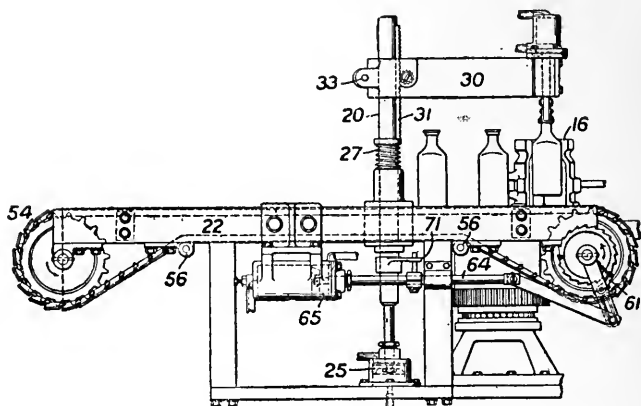
FIG. 84.

matically-operated transfer mechanism for glass-blowing machines
is mounted upon a cross-arm carried by a vertical shaft which is
lifted and rotated pneumatically to raise the article from the mould
and deposit it on a conveyer.   The take-out mechanism comprises
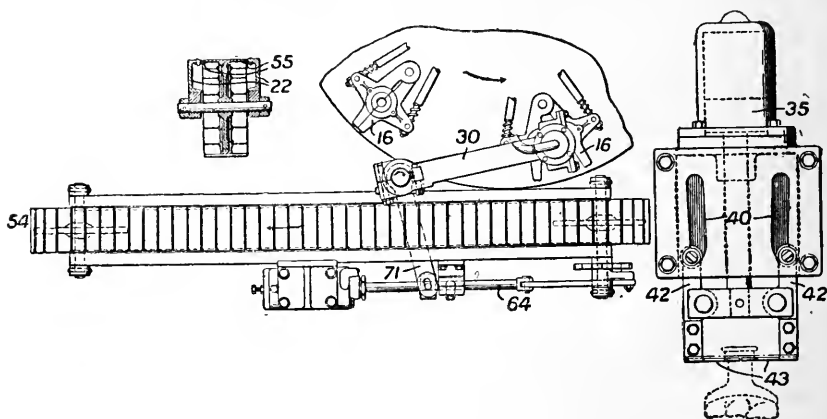
FIG. 85.

a pair of grippers, 43, which are raised and lowered by a pneumati-
cally-operated piston, 35, and caused to engage or disengage the
neck of a bottle or other article when in their lowermost position
through the action of levers, 42, engaging with cam slots, 40, of
the shape shown.   The take-out device is mounted on the end of
an arm, 30, adjustably supported by a rack, 31, and clamping

device, 33, on an upright shaft, 20, which is raised and lowered by
a pneumatically-operated piston, 25.   A buffer spring, 27, is pro-
vided to cushion the downward movement.   The arm, 30, and
shaft, 20, are oscillated, to convey the bottles from the moulds,
16, to the conveyer, 54, by a pneumatically-operated piston, 65,
and piston-rod, 64, through the intermediary of a rock arm, 71,
adjustably mounted on the piston-rod, 64.   The reciprocation of
the piston-rod, 64, also operates the conveyer band, 54, through the
ratchet device, 61, shown in Fig. 84, the arrangement being such
that the conveyer moves forward while the arm, 30, is swinging
over the moulds, 16, and remains stationary while the arm, 30,
swings over the conveyer.   Sagging of the conveyer, 54, is prevented
by metal strips, 55, riveted to the flanges of the side rails, 22, and
by idler rollers, 56, on the under side of the conveyer.   H. G. C.

192. A Steadying Device for Glass–blowing Machines.
O. Y. IMRAY, London, and the OBEAR-NESTER GLASS Co., St. Louis,
U.S.A. (Brit. Pat., No. **190225**, September 12th, 1921).—In a glass-
blowing machine as described in the preceding abstract, a steadying
device is combined with the take-out mechanism to steady the
article prior to its engagement by such mechanism and also after
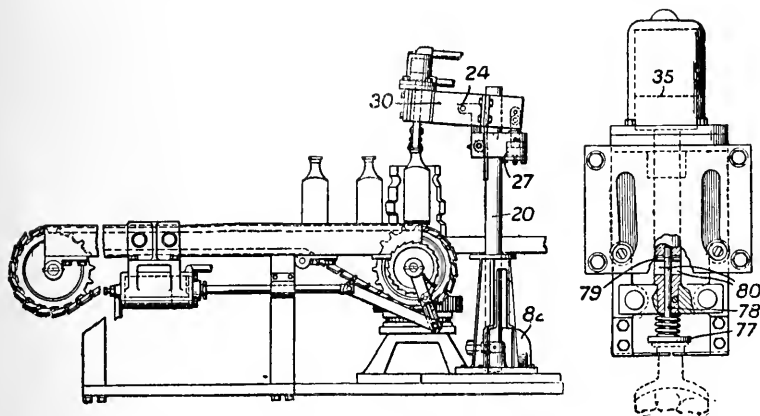
FIG. 86.

the article has been released therefrom.   The arm carrying the
take-out device may also be pivoted to swing vertically, in which
case the vertical shaft carrying the arm is given a horizontal oscilla-
tion only and not a vertical movement.   The steadying device
comprises a spring-pressed disc, 77, carried by a stern, 78, provided
with a cross-pin, 79, which is free to slide in slots, 80, formed in
the piston-rod of the piston, 35.   The arm, 30, carrying the take-
out device is pivoted at 24, and oscillated vertically at the proper
intervals by a pneumatically-operated piston, 27.   The vertical
shaft, 20, is oscillated horizontally by a pneumatically-operated
piston working in a cylinder, 82, mounted at the base of the shaft.
                                                            H. G. C.

193. Automatic Glass Forming Machine. C. R. LOTT, Washington, U.S.A. (Brit. Pat., No. **190987**, June 23rd, 1921).— A forming-machine for use in conjunction with an automatic feeding-device is provided with means, mounted on and carried by the mould support, for positioning each mould in turn beneath the delivery orifice of the feeding device.   The machine consists of a table, 4, which is rotated step by step and carries pairs of moulds, 23, 23a.   Each pair of moulds is associated with a cam, 33, that is rotated about a vertical shaft, 18, and controls the operation of the moulds and the feeder.   The table is provided with radial grooves, 49, one of which is adapted to register at every stoppage
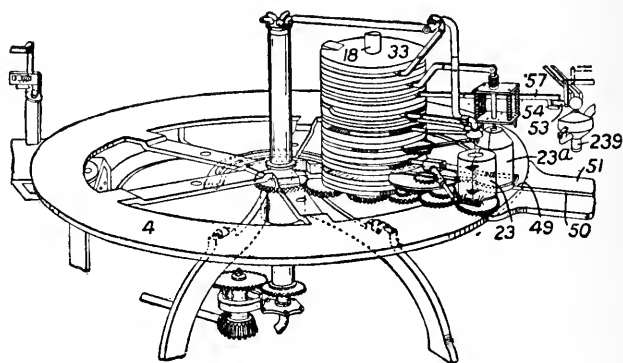
FIG. 87.

of the table with a groove, 50, on a platform, 51, leading to the furnace, and the parison mould, 23a, is provided with a lug on its under surface which slides in the grooves.   The mould is moved outwards when the table stops and comes to rest beneath the feeder, 239, and after receiving a charge of metal is returned to the table.   The feeder may be of the type described in Specifications 187661, 190737, or 190986.*   These devices have air valves, shearing devices, and valves for controlling the flow of metal from the furnace, all of which are operated in proper sequence by an elbow lever, 53.   The lever, 53, is engaged by a recess, 54, in the end of a lever, 57, one of which is associated with each pair of moulds and is actuated by a cam, 33.   H. G. C.

194. Device for Removing Glass Articles from Moulds. R. F. HALL, Wythall, near Birmingham (Brit. Pat., No. **189918**, June 7th, 1921).—A device for ejecting or facilitating the removal of glass articles from the moulds of a forming machine, particularly a machine of the type described in Specification 165453 and 165800, comprises means for holding the glass article while the halves of the mould are being opened, and means for giving the article a slight push to disengage it from the mould bottom.   In the con-

* For the two latter see this Journal, ABS. 1923, Nos. 202 and 203.

struction shown, the mould, 11, is pivoted to a swinging table, 10, as described in the above-mentioned specifications, and an arm, 15, having a forked end, 17, which engages the bottle neck, is secured to a shaft, 16, which can be oscillated by a rack and pinion actuated by a spring-controlled rod, 20. The spring normally forces the rod outwards, so that the arm, 15, is away from the mould. When the table, 10, is lowered, the end, 23, of the rod, 20, strikes a stop, 26, thus causing the arm, 15, to swing down and the forked end to embrace the bottle neck. The underside of the arm, 15, near the fork, 17, is provided with a wedge-shaped portion, 25, which engages the rim of the mould. The stop, 26, is controlled
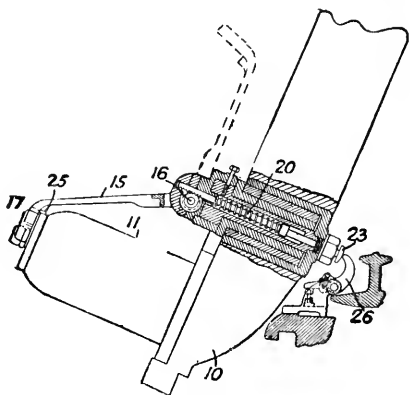
FIG. 88.

by a spring, so that it yields when the rod, 20, makes contact. When the mould is opened, the pressure of the spring controlling the stop forces the wedge, 25, to enter between the mould halves and the fork, 17, gives the bottle neck a push which frees it from the mould. In a modification, the fork on the arm moves in a plane parallel with the face of the table, 10, and the movement of the arm is effected by means of a cam.   H. G. C.

195. An Improved Mould for Bottle-making Machines.
T. A. BRAGG and THE OWENS BOTTLE CO. (U.S.A. Pat., No. **1439355**, December 19th, 1922.   Filed March 25th, 1920, No. 368612).
—The invention consists in attaching to the outer edge of the bottom plate of each fin-ishing-mould, 6, of an Owens machine, a plate, 25. The bottles, as they fall from the mould, strike this plate which thus shields the bottom from the rapid wear that is caused, at present, by the bottles striking the edge.   G. D.
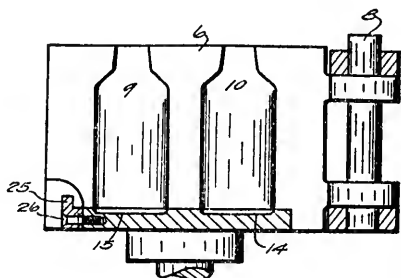
FIG. 89.

196. Mould for Pressed Glassware having Projections.
H. R. BOALS, Corning, New York, Assignors to THE CORNING GLASS WORKS, Corning, New York, U.S.A. (U.S.A. Pat., No. **1449808**, March 27th, 1923.   Filed November 8th, 1921, No. 513745).—
This invention refers particularly to the construction of moulds

for pressed ware with knobs or projections, and for the automatic emptying of such moulds merely by inverting them.   Fig. 90 shows
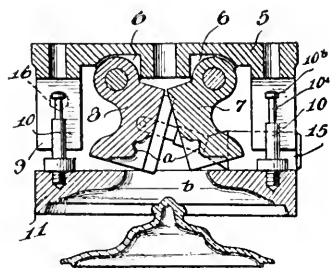
FIG. 90.

such a mould inverted for the removal of a glass lid.   It consists of a base plate, 5, having a pair of integrally formed ears, 6, to each of which is pivoted one of a pair of sectional auxiliary mould members, 7 and 8, which when closed form a cavity, *a*, for forming the knob and the restricted neck.   Each of these sections is provided with a weight, 15, so secured and positioned as to assist these hinged portions, 7 and 8, in opening when the mould is inverted.   The amount of opening is limited by the weights falling on and resting on the main mould, 11, thus preventing damage to the auxiliary moulds, which would occur if they were allowed to swing too far open.   When in the upright position the weights, 15, close the auxiliary moulds.

S. E.

197. Apparatus for the Manufacture of Pressed Glassware. W. H. McSwain, Moundsville, West Virginia, U.S.A. (U.S.A. Pat., No. **1384967**, July 19th, 1921.   Filed November 29th, 1916, No. 341506).—The primary object of this invention is to provide a machine for automatically performing all the various operations required in the manufacture of pressed glassware, from the flowing of the glass from the melting furnace to the finishing of the pressed article.   An endless chain is fitted with the press moulds, and arranged so that on carrying the moulds through the length of the upper run of the chain, they move along a horizontal platform. Fitted above this platform is a constantly rotating funnel through which glass gobs are fed into the several moulds as they pass under its mouth in their journey along the platform.   Adjacent to this funnel is a pressing mechanism fitted to supports which are secured to a base on each side of the conveyer chain.   This base can move backwards and forwards along the platform for a limited distance, to allow the plunger which is operated by fixed cams to keep in register with the press mould until the glass is sufficiently pressed to retain its shape.   The press carriage is then returned to its normal position by the action of a spring.   Immediately beyond the region in which pressing occurs the moulds are enclosed in an oven in which the glass is subjected to reheating and interior fire polishing by gas jets.   In passing over the end sprocket, the moulds deposit the glass articles on to supports, which are mounted on a conveyor, and carry the glassware through a second reheating chamber in order to fire polish the exterior.   S. E.

198. Machine for Making Pressed Glassware. T. C. Moorshead, Alton, Illinois, U.S.A. (U.S.A. Pat., No. **1445345**, February 13th, 1923.   Filed November 17th, 1917, No. 202637).— A cylindrical framework is mounted on a base in such a way that

it can rotate continuously about a central column which carries a number of fixed cams and grooves designed to operate the various parts of the machine.   Around the periphery of this cylindrical frame are mounted a number of complete units for gathering glass, pressing it to shape, and ejecting the ware.

The gathering is accomplished by the mould, 54, Fig. 91, dipping into the molten glass under the action of a cam groove, 45, which operates a rack, 39, and this in turn, meshing with the segmental rack, 38, causes a rocking of the lever, 33, to which the mould-carrying block, 31, is connected by the rod, 32.   During the time the gathering mould is passing over the molten glass it is connected to the exhaust pipe, 71, through a ported sliding valve, 69, and the
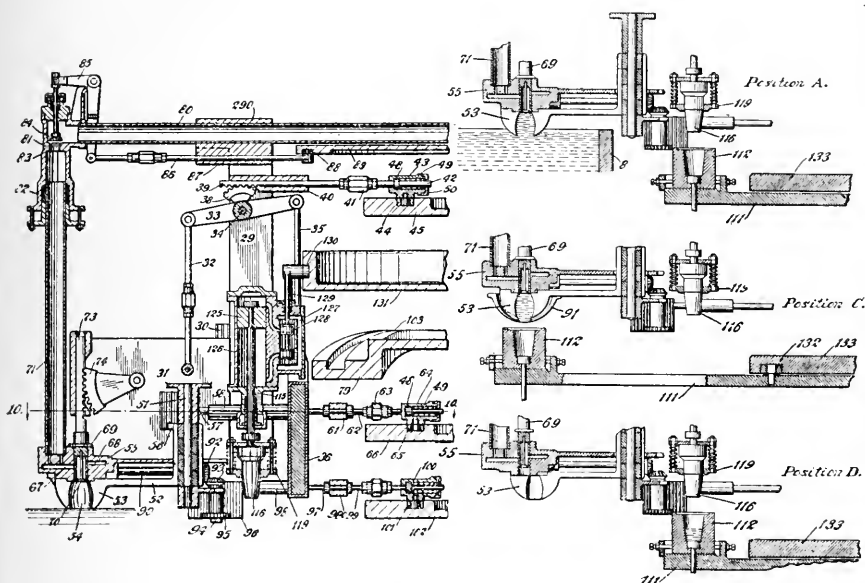
FIG. 91.

port, 67.   Thus the mould is completely filled with glass.   As the mould rises from the surface of the molten glass, shearing members, 91, close around and underneath the mould mouth thus severing the gathered glass from the remainder and retaining it in the mould, which is then raised sufficiently to permit of its passing over the edge of the glass container or pot.

Mounted on the base of the rotating frame are a series of radial guideways on which the corresponding mould carriers, 111, can slide.   During the time that gathering is taking place, these carriers, and their attached moulds, 112, are in the retracted position indicated as position A, Fig. 91, but immediately the gathering mould has passed over the edge of the glass container, the forming mould, 112, is carried forward under the action of the cam roller, 132, until it stands immediately below the closed mouth

of the gathering mould (position C). The shear members, 91, and the mould halves, 53, are separated and the glass allowed to fall into the forming mould, 112, which is then withdrawn by the cam roller, 132, to position D. The forming plunger, 116, is forced downwards into the glass under the action of compressed air on the piston, 125, moving in the cylinder, 126. The supply of compressed air, determining the time of pressing and the withdrawal
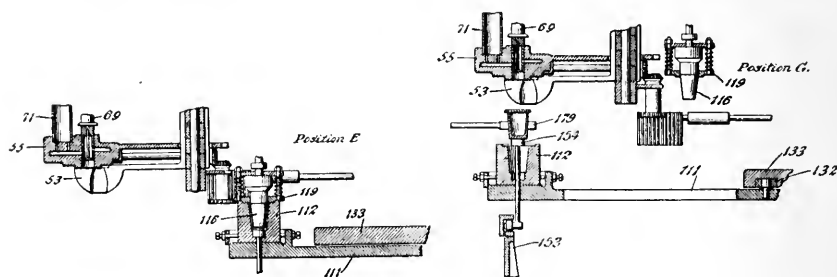
FIG. 92.

of the plunger is controlled by the cam roller, 130, and the cam, 131, which operate the sliding valve, 128, thus admitting compressed air to neither or either end of the cylinder, 126. The pressing of the glass occurs at position E.

The pressed ware is ejected by carrying the mould, 112, to its outermost position (position G) under the action of the fixed cam, 133, where the mould bottom is forced upwards by the cam, 153, and at the same time a retaining member yieldingly engages the top of the ware to prevent its being thrown out by the rotation of the machine. From this raised position the ware is taken on to a conveyor and to the lehr.   S. E.

199. An Improved Paste Mould Machine. W. J. MILLER, Swissvale, Pa., U.S.A. (U.S.A. Pat., No. **1428855**, September 12th, 1922. Filed September 23rd, 1919, No. 325617).— This invention refers to paste mould machines and is concerned with the mounting, opening, and closing of the moulds; the mounting and rotating of compressed air pipes, and the means for cooling the open moulds.

A bed, A, Fig. 93, is provided with an axial vertical standard, B, and an annular concentric raceway, 2, containing balls, 3, which support the circular base, 4, of the sleeve, C. Bushings are interposed between the standard, B, and the sleeve C, so as to allow of rotation without rocking, the rotation of the sleeve, C, being obtained by the worm, 8, and the gear, 7. An annular top plate, 10, attached to the bed covers and protects this worm gearing, and having its edges, 11 and 12, turned up forms a pan for collecting water, which is discharged through the pipe, 13. A circular mould table, D, is mounted on an axial hub, 14, passed over the sleeve, C, and held in position by the screw collar, E, and
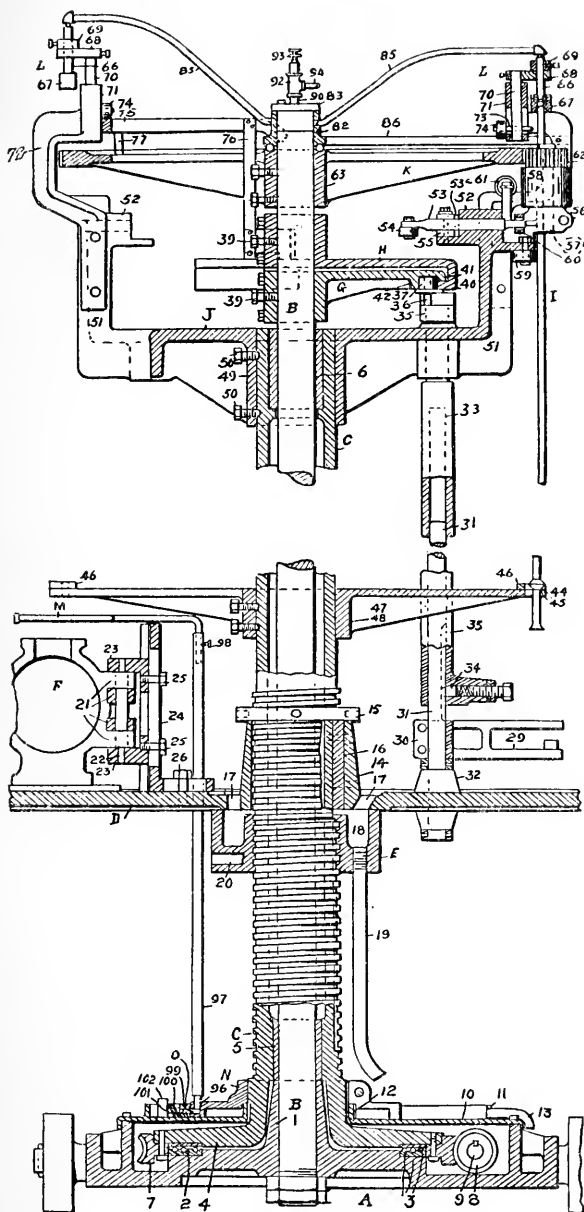
FIG. 93.

a top lock nut, 15. The hub of the table and the sleeve, C, are secured for rotational purposes by a key, 16. The collar, E, is provided with a circular trough, 18, and a discharge pipe, 19, for collecting and draining away water.

Five moulds, F, are mounted on supports, 24, adjustably secured to the table by bolts, 26, passing through slots in the feet of the supports. The moulds are provided with lugs, Fig. 94, pivotally connected by links, 28, to the arms, 29, which are secured to the

shafts, 31. Secured to these shafts are arms, 35, each pair of which is slidably connected by a pin, 36, carrying an antifriction bearing, 37. This roller opens and closes the moulds by engagement with the fixed cam and rack between the cam members, G and H, which are slidable over one another thus permitting a variation of the time during which the mould is closed.
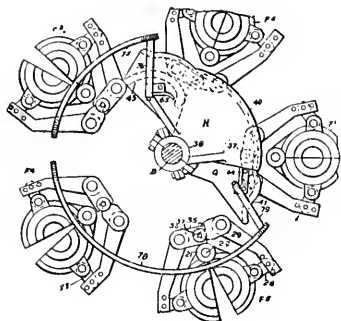
The blow pipes, I, are provided with an enlargement, 44, which engages the sockets, 45, carried on blocks, 46, at the ends of radial arms, 47. The upper ends of the

Fig. 94.

blowpipes fit into bearings carried on the platform, J, and are gripped between rubber faced rollers, 58, secured to gears, 62, which cause rotation by meshing with the fixed gear, K.

The blowheads, L, are also carried from the platform, J, by the supports, 72, and are provided with rollers, 74, which, co-operating with an undulating cam track, 75, lift the heads for the insertion or removal of irons. Compressed air is supplied to the blowing heads by the flexible pipe, 85, and passes to each mould in turn through a port in the wall of the bushing, 87. During the time the moulds are open and empty, water is sprayed on to them through the pipes, M, mounted in the form of a horseshoe above the moulds.   S. E.

200. Finishing Blown-glass Articles. J. BAILEY and THE CORNING GLASS WORKS, New York (U.S.A. Pat., No. **1352396**, September 7th, 1920. Filed August 19th, 1919, No. 318569).—Relate to a machine for finishing thin-walled, blown-glass articles, such as electric lamp bulbs, and consists of means for removing the bulbs with the moils from the blow iron, for melting the moils off the bulbs, and for finishing the necks of the bulbs ready for the lamp-making processes.

The machine comprises a table on which is mounted a turret, 30, that is rotated step by step about a vertical standard, 56. The bulb-holding devices consist of chucks, 62, resting on ball bearings in heads, 31, secured to the turret, the chucks being rotated continuously by a shaft, 57, passing through the standard, 56.

The stripper-mechanism for removing the bulbs from the blow-pipes consists of a standard, 69, having a notched upper end, 70. The operative inserts the nose of the pipe, with the bulb attached, in the notch, as shown in Fig. 95, and then pulls it out, so that the moil engages the sides of the notch and, with the bulb, is detached. The bulb and moil fall into a tray, which is cocked periodically by the mechanism, so as to deposit the bulb and its moil in a loading shoot, 66. The shaft, 71, Fig. 95, of the tray which receives the bulb, has a hooked member, 81, attached, and a latch, 82, which is depressed when a pipe is placed in the notch, 70,

FIG. 95.

engages the member 81 and prevents the tray from being rocked while a bulb is being stripped. If a bulb is defective, the operative, after stripping it, depresses the member, 81, so that the tray is
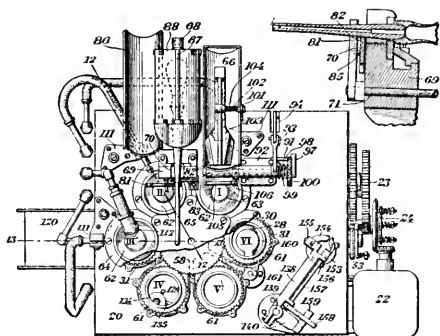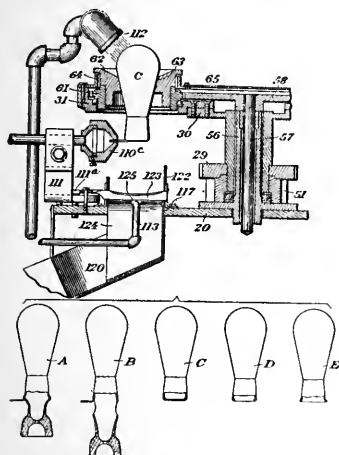
FIG. 96.
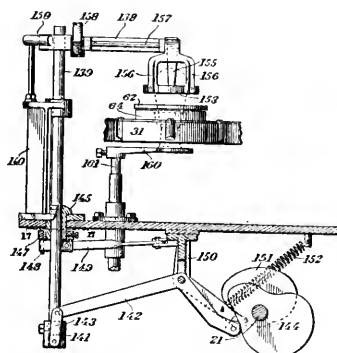
FIG. 97.

tilted in the opposite direction and deposits the bulb in a waste shoot, 86.

After receiving a bulb, the shoot, 66, turns about a shaft, 91, into the vertical position and deposits the bulb in a chuck, 62, at station I, a spring-held paddle, 103, preventing the discharge of the bulb until the shoot, 66, is approximately vertical. The bulb, now revolving continuously, has its neck heated by a gas burner,

as shown at *A*, Fig. 96, and when it is moved to station II, the neck is further heated until it elongates under the weight of the moil, as shown at *B*. At the next station III, the neck is pierced by a burner 110*c*, Fig. 96, and the moil drops off and is deflected by a blade, 123, into a shoot, 120. The thin glass of the neck tends to seal the aperture of the bulb, as shown at *C*, but this is prevented by using a pointed flame from a burner, 113, which in conjunction with a burner, 112, that heats the bulb and expands the contained air, melts the thin film of glass and causes it to form a bead around the neck, as shown at *D*.

At the next station, IV, the heated neck is pressed between an arm and a roller so that the bead is flared, as shown at *E*, Fig. 96. The bulb cools at station V, and at station VI is lifted from the turret.

The lifting device consists of an arm, 138, having at its upper end two grippers, one of which, 154, is fixed to the arm, and the other, 153, is secured to a shaft, 157, journalled on the arm. The arm, 138, reciprocates vertically and swings horizontally through an arc of about 90°. The bulb is raised from the chuck by a plate, 160, and is engaged by the grippers as the arm descends. The arm is then raised and swings clear of the chuck, and when it descends, an arm, 158, secured to the shaft, 157, strikes a stop, 159, thus opening the grippers and releasing the bulb.

G. D.

201. Glass Delivery Device. D. A. RIPLEY, Ashton-on-Mersey (Brit. Pat., No. **189168**, June 27th, 1921).—Relates to apparatus for delivering uniform charges of molten glass to moulding machines. According to the invention, a continuous stream of molten metal flows into a receptacle consisting of a large cup, 4, and a smaller one, 16. The receptacle is raised and lowered in unison with the mould table, 38, by a cam, 9. When it rises, a stationary adjustable plunger, 18, displaces some of the metal in the cup, 4, causing it to flow into the cup, 16. When the receptacle descends, the metal flows from a
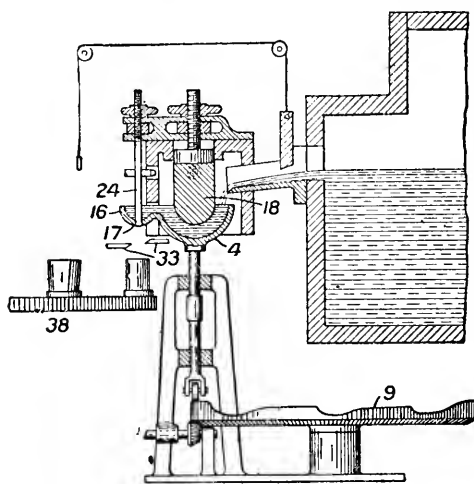
FIG. 98.

hole, 17, and is cut off by shears, 33. The hole, 17, is closed on the up-stroke by a fixed adjustable rod, 24,   H. G. C.

202. Glass Feeding Device. C. R. LOTT, Washington, U.S.A.
(Brit. Pat., No. **190737**, June 23rd, 1921).—A feeding device for
delivering charges of glass comprises a furnace having a valve-
controlled passage-way leading to a closed cup or container provided
with a discharge orifice, and means for regulating the flow of glass
through the orifice by subjecting the container alternately to
suction and compression. The container consists of a closed
funnel-shaped cup, 236, connected
with the furnace, 230, by a
passage-way, 231, which can be
closed or opened by a valve, 232.
This valve is connected by racks,
233, 322, and a pinion, 234, with
an elbow lever, 320, which is
rocked by an arm, 57, of the
forming machine. The lever,
320, also operates a valve, 300,
which is connected with the
container by a conduit, 240, and
with sources of compressed air
and vacuum. The arm, 57, also
operates shears, 276, which are
moved to and from the outlet,
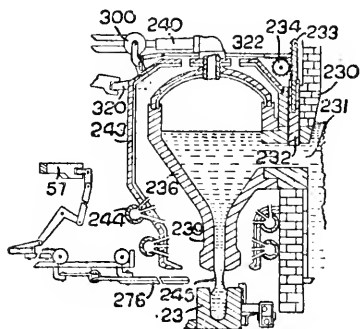
FIG. 99.

239, of the container and sever the stream, 245, of glass as it issues
from the outlet. In operation, the valve 232 is closed to cut off
the supply of the glass to the container, and immediately the valve
closes, compressed air is admitted to the container to force the
glass out into the mould, 23, of the forming machine. As soon as
a charge is supplied, the valve 300 is operated to connect the
container with the vacuum tank. The suction causes the stream
of glass issuing from the container to form a neck, where it is
cut by the shears. At the same time, the valve 232 has been
raised so that the suction causes glass to flow from the furnace
into the container. The container may be enclosed by a casing,
243, which is heated by gas burners, 244. In a modification, the
container is connected to the furnace by a siphon, the inner end of
which is alternately closed and opened by a plug.   H. G. C.

203. Glass Feeding Device. C. R. LOTT, Washington, U.S.A.
(Brit. Pat., No. **190986**, June 23rd, 1921).—Relates to a feeding
device of the kind in which a flowing stream of metal is cut into
charges by shears, a reheating device being provided for directing
a flame upwardly against the freshly-cut end of the stream, and
consists in arranging for the moulds, as they move into and out
of position below the stream, to move the reheating device away
from or towards the stream. The moulds, 23, are carried by an
intermittently rotated table, 4, as described in Specification 190987.
The moulds are arranged to slide radially, and, at appropriate
times, each mould is moved outwards on to a platform, 51, beneath
the feeder, 40, slots, 49, 50, in the table and platform respectively,
engaging and guiding a lug on the bottom of the mould. The

10*

feeder, 40, may be of any suitable kind, preferably that described in Specification 190737.   After a charge has been cut off from the stream of molten metal by the feeder shears, a burner, 341, shown in plan in Fig. 100, throws a flame against the freshly-cut end of
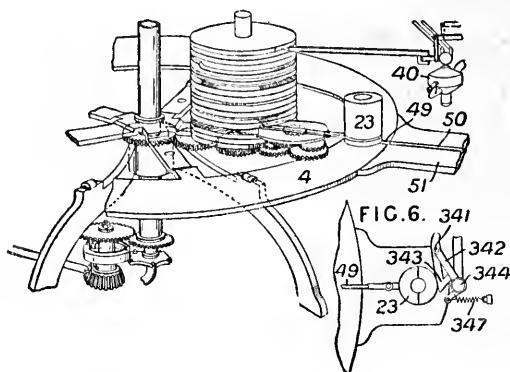
Fig. 100.

the stream.   The burner, 341, is carried by an arm, 342, pivoted at 344.   When the mould, 23, is moved to receive a charge, it strikes a finger, 343, and moves the burner away from the stream, a spring, 347, restoring the burner to its original position as soon as the mould moves back on to the table of the machine.

H. G. C.

204. Suitable Metals for Pressed Glassware Moulds. R. D. SMITH, Corning, New York, U.S.A., Assignor to THE CORNING GLASS WORKS, Corning, New York (U.S.A. Pat., No. **1449789**, March 27th, 1923.   Filed November 17th, 1921, No. 515892).— One of the most frequent causes of deterioration of moulds-plungers used in the manufacture of glassware is the cracking of the surface. This is especially marked when such parts are used for pressing glass which requires to be worked at a high temperature.   With a certain glass, a chilled, grey, cast-iron mould part failed, by cracking, after sixty hours' service, whilst an unchilled, grey, cast-iron part lasted for one hundred and twenty hours before failing. Chromium, chromium–cobalt and chromium–silicon steels withstand such work very much better than any cast iron, giving about twenty times the service of chilled cast iron.

The percentage composition of satisfactory steels is given below.

	A.	B.	C.
Chromium	13·6	10 to 15	8 to 13
Cobalt	0·6	2 to 5	—
Carbon	0·35 to 0·40	0·8 to 1·5	0·5
Manganese	0·5	—	0·5
Molybdenum	—	1	—
Silicon	—	—	4
Iron	86·5	83	84

S. E.

205. Apparatus for Moulding Glass. R. D. SMITH, Corning, New York, U.S.A., Assignor to THE CORNING GLASS WORKS, Corning, New York (Brit. Pat., No. **189126**, November 14th, 1922. Convention date, November 17th, 1921. Not yet accepted).—Compare preceding abstract.   H. G. C.

206. Process for Making Rolled Glass. CHANCE BROS. and Co., LTD., and A. L. FORSTER, Smethwick, Staffordshire (Brit. Pat., No. **191267**, December 17th, 1921).—In a process for making rolled glass in which a number of plates or sheets are rolled from one charge, d, of molten glass, the sheets, g, while in transit between the rolling machine and the lehr, are passed into a tunnel or the like, h, which is adapted to maintain the plates at a sufficient
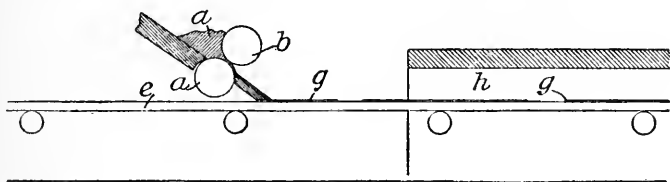
FIG. 101.

temperature to keep them intact. The plates as they emerge from the rolls, a, b, are cut into convenient lengths, and immediately the cut is made, the moving table, e, is accelerated in order to carry the plates clear of the emerging glass, from which they were divided. Any suitable form of rolling machine may be used and the table, e, must be of sufficient length to receive the whole of the sheets rolled from one charge. The part of the table on which the glass rests is constructed from material of low thermal conductivity such as stone. The tunnel, h, is heated in any convenient manner.
                        H. G. C.

207. Drawing Glass Sheets. E. C. R. MARKS, London, and THE LIBBEY-OWENS SHEET GLASS CO., Toledo, Ohio, U.S.A. (Brit. Pat., No. **189494**, August 3rd, 1921).—An apparatus for drawing glass in flat sheets comprises means for securing or severing the sheet as it is drawn upwards, and a swinging carrier which is adapted to clamp the scored upper section of the sheet and deposit it upon an horizontal carrier which is movable to carry the sheet out of the path of the clamp. The tank, 1, has a firehearth or drawing-tank, 2, the temperature of the metal at the drawing point being regulated by adjustable water-coolers, 6, and top tiles, 4, which are carried by water-cooled supports, 5. The sheet is drawn upwards by endless chains, 14, connected by grip bars, 15, which grip the thickened edges of the sheet between them, leaving the body of the sheet free from contact. Spring-pressed rolls, 20, bear against the middle part of the chain and keep it in contact with the sheet. The sheet, 30, leaves the drawing mechanism through a slot between inclined roof plates, 28, the slot being

10*–2

closed by strips, 31, of asbestos to prevent broken glass from falling between the chains.   Above the slot the sheet is scored by a cutter, 36, which acts against a backing-roll, 32.   The cutter, 36, is spring pressed against the sheet and is attached to one link of an endless chain, 34, that runs through a guide way, 33, parallel with the face of the sheet.   The chain is driven intermittently so that the cutter scores the face of the sheet at suitable intervals.   The guide way,
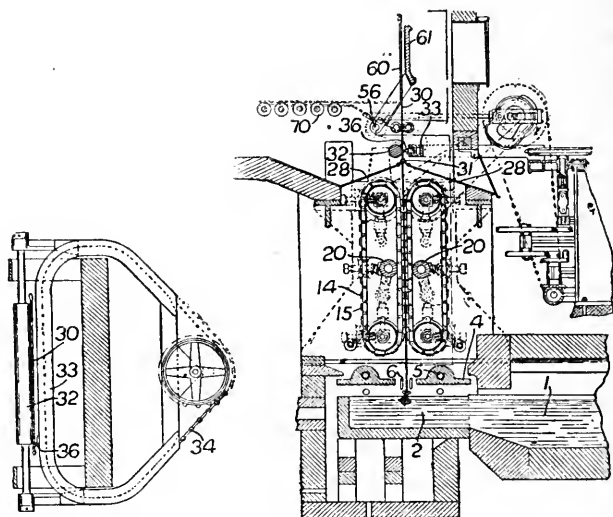
Fig. 102.

33, is inclined to the horizontal so that the cutter rises as it traverses the sheet and keeps the scored line at right angles to the edges. Above the cutting device, the sheet passes between a frame, 60, and a clamping-plate, 61, both of which swing about a shaft, 56. After the sheet has been scored, the plate, 61, swings down into the horizontal position, thus successively clamping the sheet against the frame, 60, breaking it along the scored line, and then carrying it down into the horizontal position where it is deposited on rollers, 70, that convey it to the lehr.   H. G. C.

(Brit. Pat., No. **189495**, August 3rd, 1921).—In a further form, the mass of molten glass is drawn upwardly from a supply of the

Fig. 103.

metal, passing the mass, while in a highly heated plastic condition, laterally over a bending member, and then stretching it to size to form a sheet.   The glass is drawn initially from the supply, 2, by means of a bait, and while the glass is still in a mass formation,
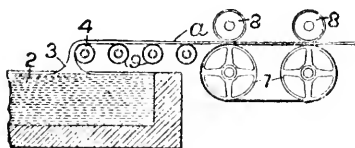
as at **3**, it is drawn laterally over a bending member, 4.   This member may consist of a roll, as shown, or a stationary member. The sheet, *A*, is drawn horizontally from the member, 4, by drawing-means, 7, 8, and is reduced in thickness or stretched to size.   Other rolls, 9, may be used to support the sheet between the member, 4, and the drawing means.

Another process (Brit. Pat., No. **189496**, August 3rd, 1921), consists in drawing the portions forming the opposite surfaces of the sheet from masses of metal arranged at different levels with a flowing connection between the upper and lower levels.   In the construction shown, the cooling end, *A*, of the tank furnace is joined on to a slab which has horizontal portions, *H*, *J*, at different

levels and a vertical portion, *H'*, the temperature of the slab being maintained by a heated chamber, *I*, beneath.   Heated chambers, *F*, *K*, formed by lip tiles, *G*, *L*, respectively, are arranged over the horizontal portions, *H*, *J*, of the slab.   In operation, metal from the chamber, *A*, runs down over the slab and is drawn
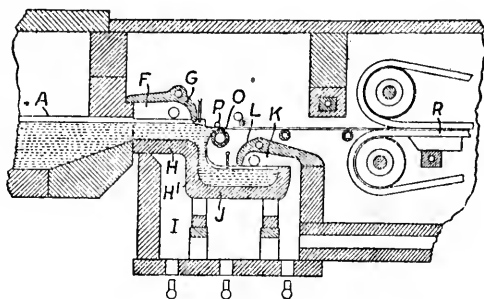
FIG. 104.

away horizontally in a sheet over a cooled idler roll, *O*, the edges of the sheet passing between edge rolls, *P*.   Thus, the upper surface of the sheet is drawn from the metal on the slab *H*, while the under surface is drawn from the metal on the slab *J*.   The roll, *O*, and the plane of the drawing-table, *R*, may be arranged above or below the surface of the metal on the slab *H*.   The supply of metal on the portion, *J*, of the slab is maintained by the stream flowing down the portion, *H'*, or it may be maintained by auxiliary streams flowing down passage ways formed at the sides of the slab.

<div align="right">H. G. C.</div>

208. Drawing Glass Sheets.   E. C. R. MARKS, London, and THE LIBBEY-OWENS SHEET GLASS CO., Toledo, Ohio, U.S.A. (Brit. Pat., No. **191097**, August 3rd, 1921).—Relates to a method of drawing glass in flat sheets and consists in causing the molten glass to flow directly, and in a continuous and unimpeded manner, from the main supply over the surface of a slab to form a shallow pool of substantially uniform depth or thickness, and subjecting the glass from the pool, as it flows from the discharge end of the slab and while it is unsupported, to a drawing stress to stretch the glass to a uniform predetermined thickness.   The glass is melted in a tank, 10, and flows through a cooling tank, 11, to the drawing chamber, 12, its temperature being regulated by arches, 18, 23, a flue, 20,

dampers, 21, 35, burners, 22, and water-coolers, 28. The bottom
of the drawing chamber is formed by a tile, 13, on which the glass
collects in a shallow pool, and having a free lateral outlet at its
forward end from which the glass is drawn away in a sheet. The
tile, 13, is supported on walls, 37, which form a chamber, 38, heated
by burners, 39, for maintaining the temperature of the pool of glass
on the tile. The drawing mechanism comprises drawing rolls, 101,
and edge rolls, 120. This mechanism is placed in such a position
that the roll, 101, is at a distance from the lip of the tile, 13, which
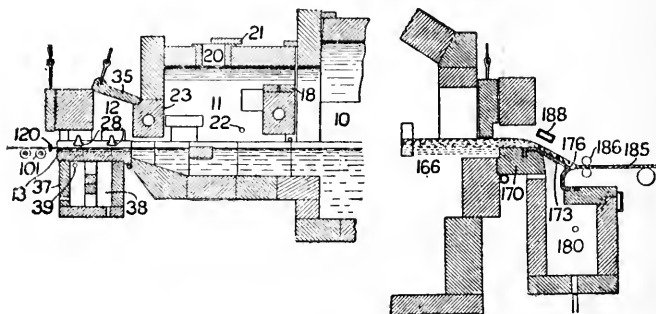
Fig. 105.

is sufficient for the sheet to draw to the desired thickness and to
have acquired a glaze, so that when it makes contact with the roll,
its surface is not marred. In a modification, shown in Fig. 105, the
glass runs from a tank, 166, over a tile, 170, and down an inclined
slab, 173, having a rounded nose, 176, from which the sheet, 185,
is drawn. The slab is preferably of nichrome steel and forms the
top of a heating chamber, 180, by which the temperature is regulated.
A water-cooler, 188, assists in regulating the temperature of the
glass. The sheet is drawn away horizontally by any suitable
mechanism, the distance of the first rolls, 186, from the slab being
adjusted as before to allow the sheet to stretch and to cool sufficiently
to avoid marring.   H. G. C.

209. Drawing Glass Sheets. E. C. R. MARKS, London, and
THE LIBBEY-OWENS SHEET GLASS CO., Toledo, Ohio, U.S.A. (Brit.
Pat., No. **189493**, August 3rd, 1921).—Apparatus for drawing glass
in flat sheets comprises a pot having oppositely-disposed overflow
lips, an endless series of slotted tubular sections adjacent to each
overflow lip, and means for moving each series vertically past the
adjacent lip, the metal flowing over the lips being received by the
sections to overcome the narrowing tendency of the sheet and to
assist in the drawing. The body of metal, 5, Fig. 106, from which
the sheet is drawn is contained in a pot, 2, provided on opposite
sides with channelled lips, 4, over which the metal can flow.
Mounted on each side of the pot are upright frameworks, 15, carry-
ing endless chains, 18, the links of which travel upwards close to

the lips, 4. The frames, 15, are mounted on wheeled trucks, 9, which may be moved to and from the pot, and one of them carries a motor, 19, which drives a shaft, 20, that transmits the drive to the chains. Each chain, 18, as shown in sectional plan in Fig. 106, has hinged to it the halves, 27a, 27b, of short tubular sections, 27. These members are so arranged that on the vertical run of the chains they are placed end to end, thus forming a continuous
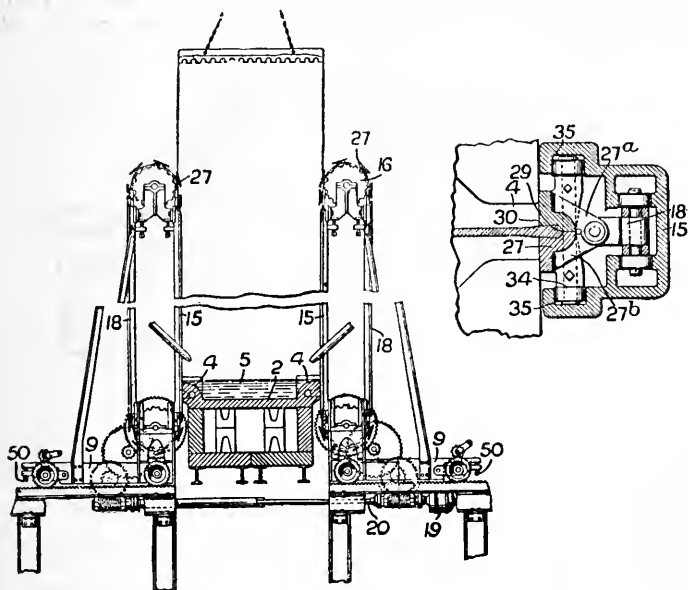
Fig. 106.

member having a longitudinal channel, 29, which is narrower at the end, 30, that runs close against the lip, 4. Guide rollers, 34, in the sections run in channels, 35, in the frame, 15, these channels, 35, being so arranged as to guide the sections and keep them closed on the vertical runs, and to open them when they turn over the upper sprocket wheels, 16. In operation, the draw is started by a bait, 15, in the usual way. As the draw proceeds, the metal flows over the lip into channels, 29, of the sections, 27, suction being applied to apertures in the sections to facilitate the inflow of metal. The thickened edges of the sheets which form in the channels draw the sheet and overcome its tendency to narrow. The frames, 15, may be tilted by means of screws, 50, to allow for the contraction of the sheet as it cools.   H. G. C.

210. Method for Drawing Sheet Glass. J. P. Crowley and The Libbey-Owens Sheet Glass Co. (U.S.A. Pat., No. **1428533**, September 12th, 1922. Filed May 16th, 1919, No. 297667).—The invention consists of a machine for drawing sheet glass continuously,

and comprises a rotating body, 7, Fig. 107, square in cross-section, over which the sheet passes and the rotation of which draws the sheet from the mass of metal, 4. The rotor, 7, has flat sides and its corners are formed by steel bars, 8. The sharp corners take the pulling strain and allow the sheet to conform to the flatness of the sides.
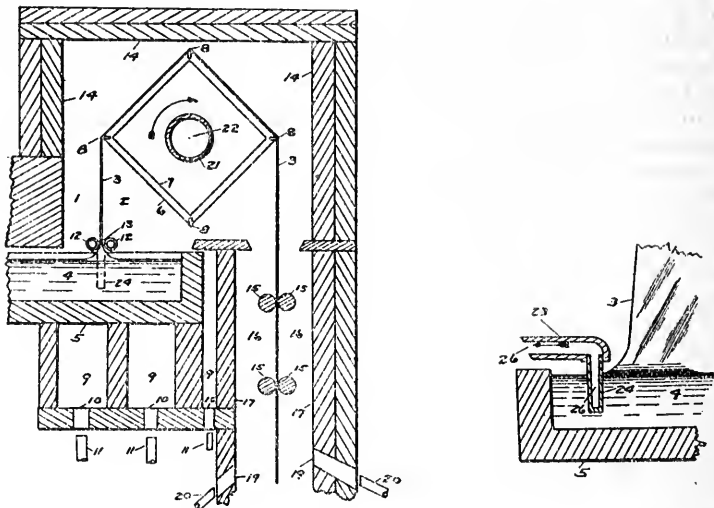
FIG. 107.

The width of the sheet is maintained by devices, shown in section in Fig. 107, consisting of pipes, 23, having side pieces, 24, that dip into the glass and have fine slots cut through their walls. The air is sucked out of the tube, 26, and the atmospheric pressure on the surface of the glass forces it against the member, 24, thus keeping the edges of the sheet drawing from the same points.

G. D.

211. Drawing Sheet Glass. A. E. FOWLE and THE LIBBEY-OWENS SHEET GLASS Co. (U.S.A. Pat., No. **1447654**, March 6th, 1923. Filed October 3rd, 1921, No. 504970).—Relates to the drawing process described in U.S.A. Pat., No. **1394283** (see this JOURNAL, ABS. 1922, **6**, No. 77), wherein a pair of sheets are drawn from the one mass of glass and after they are partly set, pass in contact with one another around a bending roller. According to the present invention, the sheets as they enter the lehr are separated and are conveyed individually through the lehr from which they emerge on to individual cutting tables. G. D.

212. A Width–maintaining Mechanism for Drawing Sheet Glass. C. A. ROWLEY and THE LIBBEY-OWENS SHEET GLASS Co. (U.S.A. Pat., No. **1444039**, February 6th, 1923. Filed December 13th, 1920, No. 430195).—An apparatus for drawing sheet glass

is provided with a width-maintaining mechanism comprising members rotating on axes parallel with the sheet edges for simultaneously pulling the sheet laterally and longitudinally, the pull being constantly exerted at a series of constantly shifting points along the sheets edge.

Fig. 108 shows the invention applied to sheet-drawing apparatus of the Colburn type, in which the sheet, 1, is drawn upwardly from the metal, 2, and turned around a bending-roller, 4. The width-maintaining device consists of vertical cylindrical members, 7, having conical lower ends, and mounted on each side of the sheet at its edges. On the outer surface of each member, 7, are a series of steep-pitched threads, 9, which engage the glass. The cylinders, 7, are pressed together and are driven by suitable means.

FIG. 108.

The rollers are rotated at such a speed that the threads will sweep across the somewhat plastic surface of the sheet at a faster speed than the sheet is being drawn. The sheet is thus stretched towards its edge and wrinkles and corrugations are removed.   G. D.
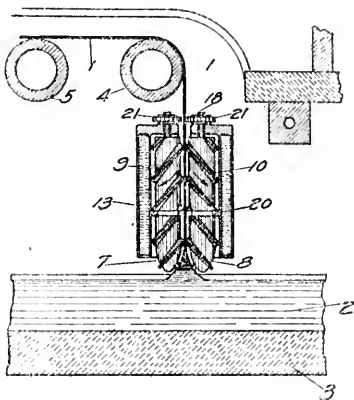
213. Drawing Sheet Glass. J. P. CROWLEY, C. A. ROWLEY, and THE LIBBEY-OWENS SHEET GLASS CO. (U.S.A. Pat., No.
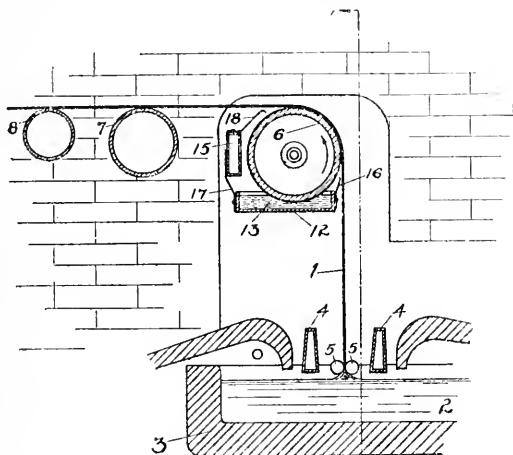
FIG. 109.

1447647, March 6th, 1923. Filed December 15th, 1920, No. 430880).—The invention relates to the Colburn process of drawing sheet glass in which a sheet, 1, is drawn from a mass of metal, 2,

and while still plastic is passed around a bending roller, 6, into the horizontal position. The bending roller, 6, is of hard metal and has a highly polished surface, but as soon as the surface becomes worn or scratched, the surface of the sheet of glass is marred.

According to the present invention, the hard metal roller is provided with a constantly renewed surface of soft metal. This is accomplished by arranging for the roller, 6, to dip into a bath, 12, of tin or lead, so that its surface is tinned. It is preferred to give the roller a greater peripheral speed than the speed of the sheet, so that a polishing action is exerted on the under surface of the sheet.   G. D.

214. Improving the Surface of Sheet Glass. M. J. OWENS and THE LIBBEY-OWENS SHEET GLASS Co. (U.S.A. Pat., No. **1440408**, January 2nd, 1923. Filed June 7th, 1919, No. 302544). —Sheet glass, which has been made by drawing in a continuous sheet and passed through a lehr, is carried by an endless conveyer through an acid bath in order to remove impurities and clear the surface of the glass.   G. D.

215. Producing Glass Sheets or Cylinders by a Flowing Method. A. BRANCART, Fauquez-lez-Virginal, Belgium (Brit. Pat., June 8th, 1921, No. **185520**).—Glass sheets and cylinders are produced by drawing molten glass upwards as it tends to flow
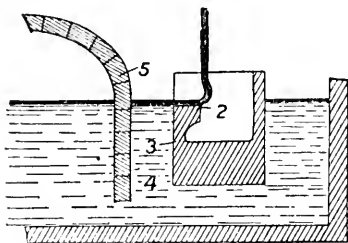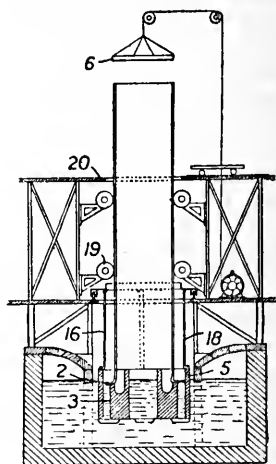
FIG. 110.   FIG. 111.

over the edge, 2, of a wall, 3. Fig. 110 shows a form of apparatus for drawing plane or curved sheets and Fig. 111 a form for drawing cylinders. Glass from the surface of the furnace outlet is prevented from passing over the overflow wall by a plate or ring, 5, dipping into the molten metal so that only metal from the deeper portion of the furnace outlet can enter the passages, 4. Uniformity

of density may be secured by rotation of the apparatus, as shown in Fig. 111, the ring, 5, carrying the overflow wall, 3, being in this case suspended by rods, 16, 18, from a rotating ring. The initial raising of the sheet or cylinder is effected by a bait, 6, after which the cylinder, etc., are gripped by rollers, 19, and raised to an operating-platform, 20, where sections are cut off by a heated platinum wire or other device and operated upon as desired. Undulated or curved sheets may be obtained by shaping the overflow wall and bait as desired.   H. G. C.

216. Preventing Devitrification and Striation during the Drawing of Sheet Glass. J. WHITTEMORE and THE LIBBEY-OWENS SHEET GLASS Co. (U.S.A. Pat., No. **1436421**, November 21st, 1922. Filed November 26th, 1920, No. 426378).—In order to prevent devitrification occurring on the surface from which the sheet is drawn, causing lines and striations in the sheet, the metal is maintained in a sufficiently hot condition to flow freely from a pool 2, without danger of devitrification. It pours over a lip, 10, on to the surface of a revolving cylinder, 14, whence it is drawn away in sheet form, either vertically downward, as shown, or horizontally. The cylinder, 14, is made of suitable refractory material, such as fireclay, and is mounted on a water-cooled axle. Burners and water-coolers

FIG. 112.

enable the temperature of the metal in the cylinder, 14, to be regulated.   G. D.
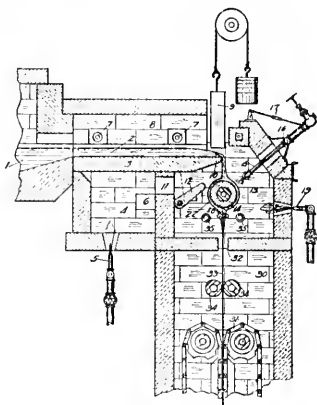
217. Flattening Sheet Glass during the Drawing Process. S. B. HENSHAW and THE LIBBEY-OWENS SHEET GLASS Co. (U.S.A. Pat., No. **1447661**, March 6th, 1923. Filed August 28th, 1920, No. 406577).—The invention consists of means for flattening, by stretching laterally, sheet glass as it is produced by any process of drawing a continuous flat sheet. The invention is particularly applicable to the Colburn process, in which the sheet, after being drawn vertically upwards, is turned into a horizontal plane and is drawn along by clamping-members which grip the sheet against an endless moving table.

According to the invention, worms carried by the clamping-members, and revolved by racks fixed alongside the table, grip the edges of the sheet and draw them outwards, thus stretching the sheet laterally.

U.S.A. Pat., No. **1444038**, February 6th, 1923 (C. A. ROWLEY and THE LIBBEY-OWENS SHEET GLASS Co. Filed November 1st, 1920) describes another means of achieving the same object. In

this device, the endless carrier or draw table is made in the form
of an endless flexible chain of closely intermeshing links. The
edges of this table are composed of a series of loosely interlocked
links which are drawn outwards by cam guides as the chain proceeds
along its upper run, and thus draw apart the edges of the sheet
which are clamped against them.   G. D.

218. Machine for Bevelling Lenses. T. GREENWOOD, Bowdon,
Cheshire (Brit. Pat., No. **186228**, August 22nd, 1921).—The lenses,
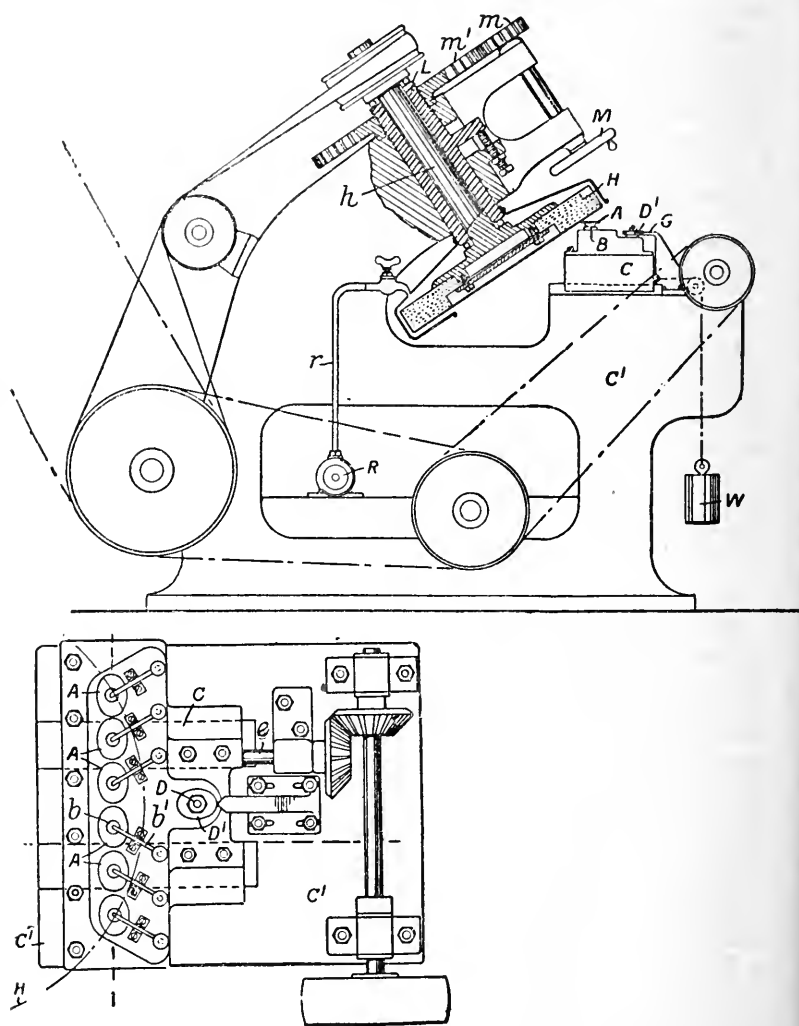
FIG. 113.

A, are mounted, by means of rubber washers, b, and pads held down by screw-operated levers, b', on spindles, B, rotatably supported in a carriage, C, which is slidable on the machine frame, C'. The sliding movement of the carriage is controlled by a rotating templet, D', having a shape corresponding with that of the lenses and carried by a spindle, D, mounted on the carriage, C, the edge of the templet being maintained by a weight, W, in contact with an abutment, G, which may be fixed to, or adjustably mounted on, the frame, C'. The spindles, B, are all driven at the same speed by spur gears mounted on the spindles, one of which is driven through spur gearing by, and at the same speed as, the templet spindle; the templet spindle is driven by means of a worm-wheel thereon which engages a worm mounted on a driven shaft, e, and slidable thereon with the carriage. The grinding-wheel, H, operates with its flat under-surface, and the spindle, h, is rotatably carried by a sleeve, L, which is adjustable axially by means of a hand-wheel, M, and gearing, m, m', to compensate for wear. When circular lenses are to be levelled, the carriage, C, may be locked in position. Water or other liquid is supplied to the wheel through a pipe, r, by a pump, R. H. G. C.

219. A Cylinder–Capping Device. W. WESTBURY (U.S.A. Pat., No. **1447828**, March 6th, 1923. Filed October 13th, 1921, No. 507404).—A cylinder cracking device consists of an electrically heated wire adapted to be passed round the cylinder, a support for the wire provided with means for connecting one end with one side of an electric circuit, and a movable circuit-closing device which can make contact with the other end of the wire or with any point in its length, so that only a portion of the wire can be heated if desired. The device enables thicker portions of the cylinder to be heated for a longer time than the thinner portions. G. D.

220. Grinding and Polishing Lenses. M. BENTZOW, 41, Avenue de Neuilly, Neuilly-sur-Seine, France (Brit. Pat., April 25th, 1921, No. **183571**).—A machine described in the Specification 28823/04 for grinding and polishing bi-focal lenses, wherein inner and outer curved zones are produced on a glass disc which is subsequently cut up to form the lenses, comprises two grinding or polishing tools, which produce the inner and outer zones, respectively, the inner tool being under the control of a curved templet, which causes the tool to move in a path corresponding to the curvature to be imparted to the inner zone. The glass disc, c, is mounted on a support, b, carried by a rotating vertical spindle, d, journalled in a bracket, f, which is adjustable on vertical guides, g, on the machine frame, a, and locked in the adjusted position by a bolt, h, engaging a T-slot in the frame. The centre zone of the disc is produced by a tool, k, carried by a spring-pressed spindle, l, journalled in a frame, m, and rotated by a flexible shaft, l^2, mounted in a housing, l^3. The frame, m, which comprises two parts hinged together at m^3, is pivoted at p^2 to an arm, p, pivoted at p^1 to the machine

frame, and the frame, m, is moved to carry the tool radially over
the glass disc by means of a handle, q. The motion of the frame
away from the centre of the disc is limited by an adjustable stop, r,
and a spring, q^1, acts on the arm, p. Near the tool, the frame
has an extension, m^2, carrying rollers, o, which bear on a templet,
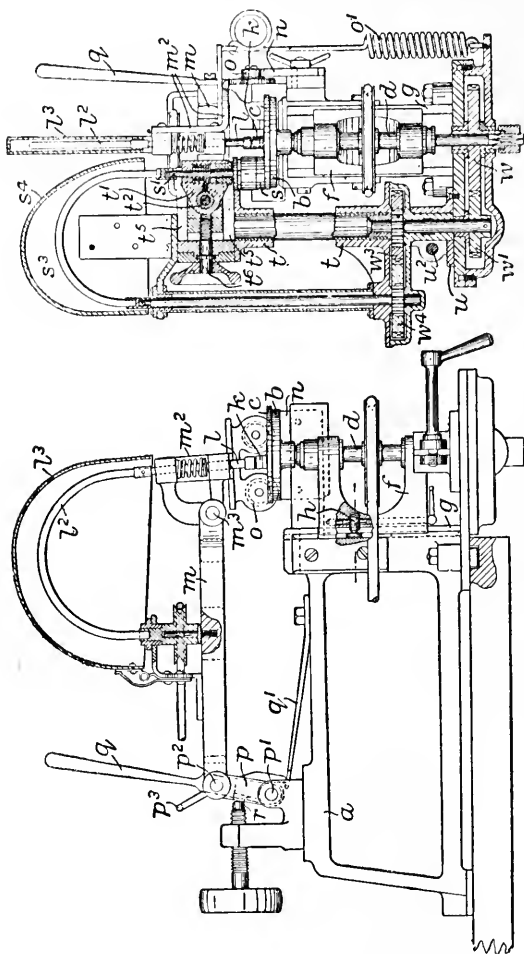
Fig. 114

n, having a curved upper surface and secured to the machine
frame. Reciprocation of the frame by means of the handle, q,
thus causes the tool to move in a path of which the curvature
agrees with that of the templet, the tool and the rollers being pressed
towards the glass disc by a spring, o^1. The outer zone of the disc
is formed by a tool, s, carried by a spring-pressed spindle, s^1, journalled
in a block, t^1, carried by a bracket, t. The bracket is mounted in a

split socket, u, in which it may be adjusted about a vertical axis and secured in an adjusted position by a screw, u^2. The spindle, s^1, is driven by a flexible shaft, s^3, mounted in a housing, s^4, the shaft being driven, through gears, w, w^1, w^3, w^4, from the spindle, d. In order to adjust the angular position of the tool to produce a convex or a concave outer zone, the block, t^1, is adjustable about a horizontal pivot, t^2, and, to adjust the tool towards or from the centre of the disc, the block is moved in guides, t^5, by a screw, t^6. To remove the tool, k, from the disc, the spring, o^1, is disconnected from the frame, m, and the frame is lifted about its pivot, p^2, to rest on a stop, p^3. The tools may both operate at the same time; or they may operate separately. According to the Provisional Specification, the frame may be reciprocated radially of the disc by a screw. H. G. C.

221. Grinding and Polishing Lenses. G. T. STEVENS, High Barnet, Hertfordshire (Brit. Pat., No. **190271**, September 27th, 1921).—Toric lenses are ground and polished by mounting a number
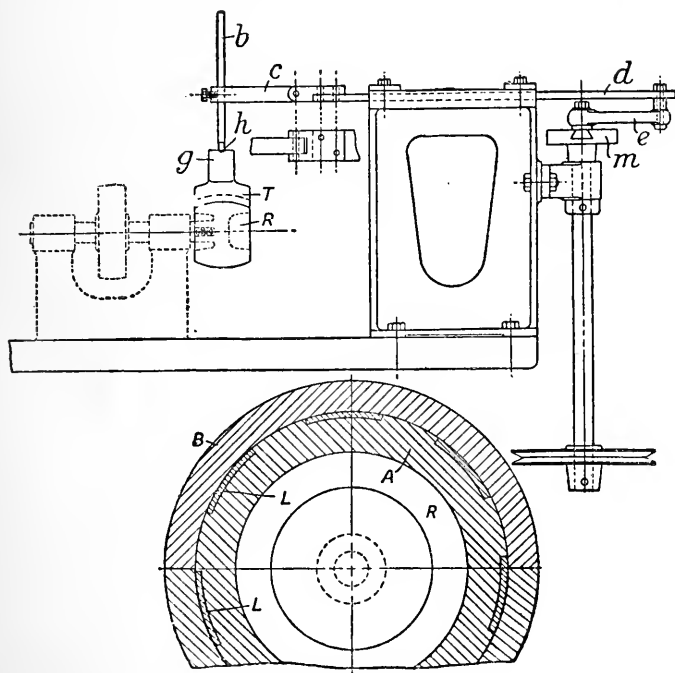
FIG. 115.

of glass blanks, L, on a spherically-surfaced runner, R, which is attached to the headstock of a lathe and rotated, the blanks being brought in succession beneath an oscillating tool, T; one curvature of the lenses is determined by the distance of the centre of the

exposed face of a blank from the centre of the runner and the other curvature is determined by the curvature of the tool in a plane containing the axis of the runner. The tool boss, *g*, has therein a depression, *h*, which is engaged by a stem, *b*, oscillation of the stem being effected, through rods, *c*, *d*, *e*, by an adjustable eccentric, *m*. The blanks are mounted on the runner by means of a layer of plaster of Paris, or like material, *A*, Fig. 115, and are positioned therein by two half rings, *B*, which are pressed together until their ends meet.   H. G. C.

X. Glassware Accessories.

222. Air-tight Glass Cements. (*Diamant*, 1923, **45**, 68).— A mixture of 95 parts of finely powdered kaolin with 5 parts of chalk was mixed as required with waterglass to give a thick paste. An alternative method was to dissolve 25 parts of finely powdered mastic and 3 parts of gutta percha (cut into small pieces) in 27 parts of chloroform or carbon disulphide. The solution was gently warmed on the water-bath and applied to the article to be cemented.

By melting 10 parts of mastic or shellac with 10 parts of Venetian turpentine and applying hot, a suitable cement was obtained, providing that the glass was warmed before application. Another process was to warm and dissolve 8 parts of isinglass in 40 parts of alcohol and stir in a solution of 5 parts of mastic and 2 parts of ammoniac gum in 45 parts of alcohol, applying the cement so made whilst hot. Finally, a mixture of 85 parts of litharge with 15 parts of pure concentrated glycerine, was kneaded together until it began to harden, when it was ready to apply.   A. C.

Reviews.

Reports of the Progress of Applied Chemistry. Vol. VII. 1922. Published by the SOCIETY OF CHEMICAL INDUSTRY, London. Price 7*s.* 6*d.* to members of the Society of Chemical Industry; 12*s.* 6*d.* to non-members, post free.—This annual review of the world of applied science, or at any rate that section which has for its basis chemistry and chemical engineering, is somewhat late in making its appearance this year. We look forward year by year in the expectation of being able to bring up to date our knowledge of the branches with which we are not in daily contact, and are inclined to become impatient when delay arises. It is, however, before us now with its wealth of information, impressing us with the importance of chemical science

in these days. There does not appear to be much change in the arrangement of the sections, although we note that Refractory Materials this year is included in the section with Ceramics and Building Materials. There are in all twenty-four sections, comprising: Plant and Machinery; Fuel; Gas—Destructive Distillation—Tar Products; Mineral Oils; Colouring Matters and Dyes; Fibres, Textiles, Cellulose, and Paper; Bleaching, Dyeing, Printing and Finishing; Acids, Alkalis, Salts, etc.; Glass; Ceramics, Building Materials and Refractories; Iron and Steel; Non-Ferrous Metals; Electro-chemical and Electro-metallurgical Industries; Oils, Fats, and Waxes, Paints, Pigments, Varnishes, and Resins; Indiarubber; Leather and Glue; Soils and Fertilisers; Sugars, Starches, and Gums; The Fermentation Industries; Foods; Sanitation and Water Purification; Fine Chemicals, Medicinal Substances, Essential Oils and Photographic Materials and Processes. These altogether occupy 530 pages. A very full index adds to the value of the Report. The Report itself ought to be purchased by all firms in any way connected with chemical industry who pride themselves on keeping abreast of the times. W. E. S. T.

Lighting in Factories and Workshops. Published by H.M. STATIONERY OFFICE, London, 1923. Price 4d. net.—This publication is a pamphlet issued by the Home Office discussing simply but thoroughly the subject of artificial lighting in factories, and pointing out how ill-lit workshops diminish efficiency and try the eyesight of the operatives. Not only is there a criticism of wrong methods, but schemes for illumination suitable for various purposes are also set out. A series of photographs illustrates some of the points at issue. W. E. S. T.

The Flow of Gases in Furnaces. By PROF. W. E. GROUME-GRJIMAILO. Translated from the French edition by A. D. WILLIAMS. (Pp. xxi+399; Figs. 194. Price 27s. 6d. London: Chapman & Hall, Ltd.; New York: John Wiley & Sons, 1923).— The design of furnaces in the past has been largely a matter of rule of thumb or of imitative methods. It was with the idea of placing the subject on a scientific basis that Prof. Groume-Grjimailo of Petrograd began to study the fundamental problem of the subject, namely, the manner in which gases flow through a furnace system. He drew the conclusion that hot, highly rarefied gases (the specific weight of air at 1365° is only one-sixth of that at 0°), moving in a medium of colder, heavier gas, possess the same properties as do light liquids flowing through heavy liquids with which they do not mix, so that the fundamental laws of hydrostatics could be applied. Thus, for instance, a gas passing through a furnace would not necessarily fill the whole of the chamber, but would flow as an inverted stream along the roof, and, for this reason, successful heating would only be accomplished if the stream was sufficiently deep to lick the material placed on the furnace bed. The theory neglected any effects of gaseous diffusion between the hot and cold gases, but in spite of this fact it has given remarkably successful

results when applied in practice. In order to determine the correct construction of any furnace, the author built models, immersed these in water, and injected currents of paraffin oil through orifices representing ports. By observing the flow of the oil, he was able so to modify details of the furnace, such as the position of the outlet ports and the height and the shape of the chambers, as to get the best results in working.

Fundamental data have also been calculated by the application of the hydrostatic theory, as, for example, the relationship between the depth of the regenerator base below the ports and the velocity of the gas entering the furnace; and between the thickness of the stream of gas flowing through a reverberatory furnace and the volume and temperature of the gas passing, and length of the furnace. The mathematical portion of the theory has been worked out by J. C. Yesmann. The original papers, published in 1911, were translated into French by L. Dlougatch and A. Rothstein, and from French into English by A. D. Williams. Value is added to the English edition by a series of appendices by A. D. Williams, which includes tables of the weights of gases at various temperatures, the relationship between the velocity heads or pressures and the velocity of the gases, formulæ and tables for brickwork construction, heat capacity and calorific intensity curves, combustion and boiler settings, and an important chapter on the design of open-hearth furnaces. The data here given, although they would perhaps benefit by some little rearrangement, are exceedingly valuable. In conclusion, it may be said that although the volume does not deal specifically with glass-works furnaces, it will prove of great assistance to those wishing to erect such furnaces on a scientific and economical basis.   A. C.

Tungsten and Manganese Ores. Special Reports on the Mineral Resources of Great Britain, Vol. I., by H. DEWEY and H. C. DINES. (Memoirs of the Geological Survey. H.M. Stationery Office, London, 1923. Price 2s. net.)—The report contains an account of the distribution of the ores of tungsten and manganese in Great Britain, the development of mines, and the relation of the British output to the world's production. Nearly all the manganese ore now obtained in Great Britain is raised in the Lleyn peninsula, Carnarvonshire, or in Merionethshire.   W. E. S. T.

I.—Glass-making Materials.

223. Proposed Tentative Specifications for Silica Sand for Glass-making. (*Bull. Amer. Cer. Soc.*, 1923, **2**, 182).—It was required that the sand should not be contaminated with stripping dirt or contain any crushed stones or pebbles which might be insoluble in the melting glass, thus producing stones. All sand should be screened, washed, and dried before shipment except where the natural conditions of the quarries would allow the production by screening only of fourth, fifth, sixth, or seventh quality sand.

The percentage composition of sands of various qualities (based on ignited samples) is shown in Table I.

TABLE I.

Qualities.	SiO_2. Min.	Al_2O_3. Max.	Fe_2O_3. Max.	$CaO + MgO$. Max.
First quality optical glass ...	99·8	0·1	0·02	0·1
Second quality flint glass containers tableware	98·5	0·5	0·035	0·2
Third quality flint glass	95·0	4·0	0·035	0·5
Fourth quality sheet glass rolled and polished plate ...	98·5	0·5	0·06	0·5
Fifth quality sheet glass rolled and polished plate ...	95·0	4·0	0·06	0·5
Sixth quality green glass containers and window glass ...	98·0	0·5	0·3	0·5
Seventh quality green glass .	95·0	4·0	0·3	0·5
Eighth quality amber glass containers	98·0	0·5	1·0	0·5
Ninth quality amber	95·0	4·0	1·0	0·5

The composition of any single quality specified should not vary from shipment to shipment more than the amounts stated in Table II.

TABLE II.

Percentage Tolerances in Composition Allowed (Based on Ignited Sample).

Quality.	SiO_2.	Al_2O_3.	Fe_2O_3.	$CaO + MgO$.
1	±0·1	±0·05	+0·005	±0·05
2	±0·5	±0·1	+0·005	±0·05
3	±1·0	±0·5	+0·005	±0·1
4	±0·5	±0·1	+0·005	±0·1
5	±1·0	±0·5	+0·005	±0·1
6	±1·0	±0·5	±0·05	±0·1
7	±1·0	±0·5	±0·05	±0·1
8	±1·0	±0·5	±0·1	±0·1
9	±1·0	±0·5	±0·1	±0·1

The sand should be prepared so that the size of grains should be rather uniform and be within the limits set in Table III.

TABLE III.

Limiting Per Cents. of Various Sizes of Sand Grains.

Through a No. 20 screen	100 per cent.
Through a No. 20 and remaining on a No. 40 screen	Not more than 60 per cent. nor less than 40 per cent.
Through a No. 40 and remaining on a No. 60 screen	Not more than 40 per cent. nor less than 30 per cent.
Through a No. 60 and remaining on a No. 100 screen	Not more than 20 per cent. nor less than 10 per cent.
Through a No. 100 screen	Not more than 5 per cent.

Screen tests were to be made with sand dried at 110°, using United States Bureau of Standards standard screen sizes.

Methods of analysis were indicated. The following method was given for the solution of the sands for any method of determining iron :

Use 0·5 gm. of sample. Fuse in platinum crucible with four times its weight of pure Na_2CO_3. Dissolve in 200 c.c. of warm water (warm on steam-bath). Dilute 15 c.c. of conc. HCl to 50 c.c. Add this from a burette slowly, drop by drop, to the solution, stirring frequently and keeping the solution cold to prevent silica from separating out. The acid addition having been made, add a small amount of pure zinc (0·05 gm.) to the solution to precipitate any platinum dissolved in the carbonate fusion. When the zinc has dissolved, filter the solution into a 500 c.c. graduated flask and proceed to determine the iron colorimetrically.   E. M. F.

*224. Recommended Specifications for Limestone, Quicklime, and Hydrated Lime for Use in the Manufacture of Glass. (*Bull. Amer. Cer. Soc.*, 1923, **2**, 6).—The specifications recommended by the Bureau of Standards in December, 1921, had been slightly modified, allowing 3·0 per cent. of SO_3 and P_2O_5 in burnt and hydrated limes.   E. M. F.

225. Silicate of Soda in the Ceramic Industries. J. G. VAIL (*J. Amer. Cer. Soc.*, 1923, **6**, 610).—A good cement (for mending saggars) was obtained by the mixture of two parts of sodium silicate and one part of powdered clay with the addition of a little water to form a thick cream. The best form of sodium silicate was that of the composition $Na_2O,2\cdot4SiO_2$, which was usually sold as a solution containing 47 per cent. solid. Clay–sodium silicate cements were also used for making the brickwork of kilns, boiler furnaces, etc., gastight. A unit of Na_2O as sodium silicate had a larger effect in reducing the viscosity of clay slip than the same amount added either as hydroxide or carbonate.   A. C.

* See this Journal, ABS. 1922, **6**, 4.

II.—Glass : Manufacture and Properties.

226. The Manufacture of Cast Glassware. M. HETTRICH (*Diamant*, 1922, **44**, 459).—In order to prevent the rapid chilling and setting of glass which occurred when it was poured by means of a ladle, the following casting device had been employed. Glass was melted in a tank furnace with a low bridge. The end-wall of the working chamber of the furnace did not reach the crown, and beyond this wall was a casting chamber which was thus heated by radiation from the furnace. A channel pierced the end-wall of the furnace and projected into the casting chamber. A casting table, set on rails, was introduced through an archway into the chamber until it lay under the spout, when glass was allowed to flow on to it from the tank. When the process was complete, the flow of glass was interrupted and the table withdrawn. In contact with the table was a plate, also on rails, and of a size practically equal to the horizontal section of the casting chamber. As the casting table was withdrawn, this plate was introduced into the chamber and so served to close it from without. Sometimes a ladle was also employed, swung on a support outside the furnace.

A. C.

227. Light Cast Plate Glass. F. WOLLNER (*Sprechsaal*, 1923, **56**, 122).—The author considered that a coming way for casting light plate glass was by first melting glass in tanks or large pots and then ladling into small pots, in which the glass could be again fined and brought to the casting temperature. A Bohemian factory making $\frac{3}{4}$-white blown glass and roofing glass, also cast light plate glass from the same tank. The method employed was to fine the glass thoroughly on Sunday, when no working-out took place, and so bring it to the requisite quality, whereby on the Monday many large sheets of up to $4\frac{1}{2}$ sq. m. could be cast. A. C.

228. The " Spiegel " Group of Glasses. E. ZSCHIMMER (*Sprechsaal*, 1923, **56**, 239, 250, 262).—In order to find the relationship between the composition and the chemical stability of glasses of the so-called " spiegel " group (that is, soda–potash–lime–silica glasses), the author studied 249 commercial glasses of which the compositions had been published by various workers and the stabilities observed either quantitatively or qualitatively. The method used was to mark the compositions of the glasses on a four dimensional diagram, and at the points obtained to indicate the relative stabilities. By this means approximate boundaries could be marked. The glasses were divided into three groups, (1) resistant (approximating to Class II of Mylius), (2) medium (Class III), and (3) bad; and the following useful rules were deduced :

(*a*) All glasses in the first two groups had a lime content lying between 7·5 and 15 per cent.

11—2

(*b*) Resistant glasses had a total alkali not exceeding 13 per cent.

(*c*) Medium glasses were those with a total alkali content from 13 to 19 per cent.   A. C.

229. Historical Sketch of the Manufacture of Plate Glass in America. C. E. FULTON (*Bull. Amer. Cer. Soc.*, 1923, **2**, 70).— The first attempt to make plate glass was at Cheshire, Mass., in 1850. No success was met with until J. B. Ford established several works in the period 1870—1895, and prior to 1880 no plate glass was made without financial loss to the manufacturer. In 1889, English methods of grinding and polishing were discontinued and the circular table machines introduced. The first continuous annealing lehr was built at Floreffe, Pennsylvania, in 1900. The potential capacity of American factories was now approximately one hundred million square feet, and 20,000 men were employed.
                                                      A. C.

230. Pyrex Glass Plant Equipment. A. E. MARSHALL (*J. Ind. Eng. Chem.*, 1923, **15**, 671).—A claim for the use to which Pyrex glass could be put in industrial plant. The freedom from corrosion was a great point gained. The physical properties of Pyrex were summarised as follows : Specific gravity, 2·25 ; specific heat, 0·20 ; elasticity coefficient, 6230 kg. per sq. mm. ; linear expansion coefficient (19° to 350°), 0·0000032 per 1° ; thermal conductivity, 0·0027 ; dielectric strength, 20 kv. per 100 mil. thickness ; specific inductive capacity, 5·75 to 5·78 ; electrical resistivity (volume), 10^{14} ohms ; electrical resistivity (surface), 10^{14} ohms at 34 per cent. humidity, 5×10^8 ohms at 84 per cent. humidity.

The use of Pyrex glass was advocated in plant where any or all of the following conditions were essential : (1) Resistance to action of acids ; (2) Purity of product ; (3) Control facilitated by transparency ; (4) Resistance to thermal shock.

The action of mineral acids was negligible, except in the case of phosphoric and hydrofluoric acids, and Pyrex glass could not be used in the production of hydrofluoric acid, or fluorides. No measurable attack was found in five hours at the fuming temperature in the manufacture of acetic anhydride. Direct flame on the glass was to be avoided. Flanged joints in pipe lines had to be of special design, and plastic cements were essential if the joints were of the socket or bell and spigot type.   V. D.

231. The Manufacture of *X*-Ray Bulbs. BRITISH THOMSON-HOUSTON CO., LTD., London, and the GENERAL ELECTRIC CO., Schenectady, New York, U.S.A. (Brit. Pat., No. **193581**, December 19th, 1921).—In the manufacture of glass receptacles such as *X*-ray bulbs having windows differing in thickness, composition, or other respects from the main receptacle, the latter is gradually heated in an enclosed space nearly to the softening point, and the window, also while heated, placed in position, the region of contact being

then fused. The parts are previously fitted by grinding, etc. The apparatus comprises a rotatable oven, 5, fitted with a removable cover, 8. The receptacle, shown as an X-ray bulb, which is made of lead glass, previously heated at about 450°, is placed in the oven, the arms, 10, 11, being locked by spring fingers, 16, 17. The temperature is raised to about 475°, when the previously heated window made of lime glass is placed in position and held therein by a pad of refractory material. The oven is then rotated, a pointed flame being applied to the edges of the window.   H. G. C.
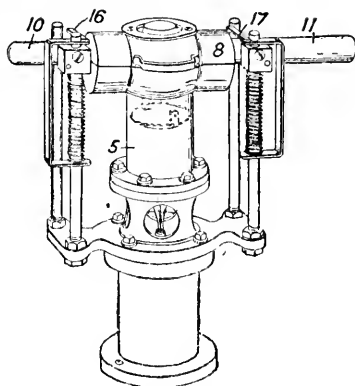
Fig. 116.

232. Methods for Manufacturing Fused Silica Ware. BRITISH THOMSON-HOUSTON Co., LTD., London, and the GENERAL ELECTRIC Co., Schenectady, New York, U.S.A. (Brit. Pat., No. **194092**, January 31st, 1922).—A method of making articles of fused silica having a glazed external surface consists in confining a mass of silica particles in a refractory mould of desired shape,
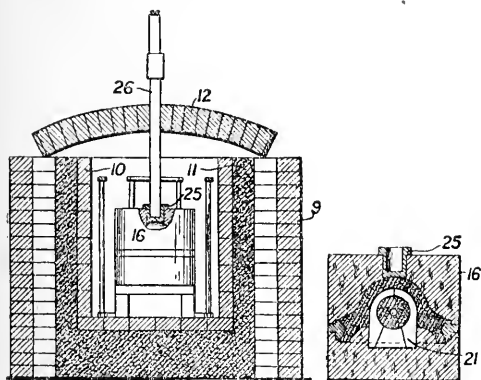
Fig. 117.

and then heating the mould and contents to a temperature sufficient to soften and coalesce the particles whilst retaining the configuration of the inner surface of the mould. The furnace in which the silica is fused comprises an exterior wall, 9, a highly refractory interior wall, 10, with an intervening layer of heat insulating material, 11, and a removable roof, 12. The heater consists of rods of carbon arranged in series and connected to electric conductors. Comminuted silica is placed in a mould, 16, which is made of carbon and has suitably shaped core members, 21, also of carbon. A short carbon tube, 25, which forms part of the upper portion of the mould, receives a pyrometer, 26. The silica is firmly packed in the mould and the furnace is raised to a temperature of about 1750°. The silica grains soften and coalesce whilst maintaining the shape of the mass. When cooled, the moulded article has a smooth, glassy

surface and contains minute cavities distributed throughout the mass.   The mould shown is intended for making electric insulators.

<div align="right">H. G. C.</div>

233. The Preparation of Transparent Fused Silica Ware.
BRITISH THOMSON-HOUSTON CO., LTD., London, and the GENERAL
ELECTRIC Co., Schenectady, New York, U.S.A. (Brit. Pat., No.
195508, March 8th, 1922).—A method of making bubble free,
transparent, silica glass consists
in heating a mass of crystalline
quartz to a fusing temperature
whilst mechanically supporting
the mass to prevent displace-
ment of the particles resulting
from the disintegration of the
crystalline quartz.   Fusion is
carried out in an electric vacuum
furnace consisting of a tank, 1,
containing a crucible, 15, a
helical resister, 6, and a screen,
13.   A mass, 16, of clear, crystal-
line quartz is placed in a
crucible, 15, which is packed
with granular or powdered
graphite, the top of the crucible
being closed by a plug of
graphite, 18.   The packing pre-
vents mechanical displacement
when the crystal shatters, and
the particles then coalesce and
form a mass of clear, amorphous
silica.   In a modification a mass
of crystalline quartz is ground
or otherwise shaped to a cylinder
to fit into the crucible, and a plug is screwed into the top of the
crucible to confine the mass.   Specification 189926 is referred to.
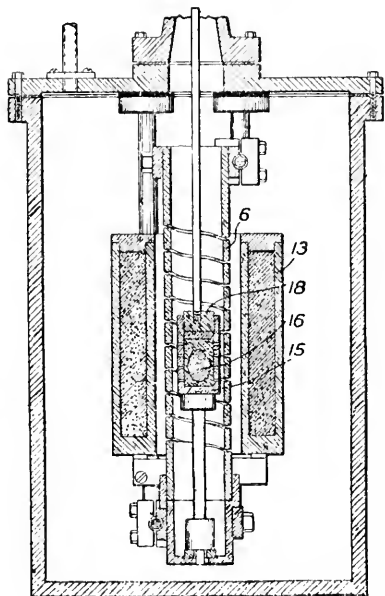
FIG. 118.

<div align="right">H. G. C.</div>

234. Patents Regarding the Manufacture of Quartz Goods.
W. SCHUEN (*Ker. Rundschau*, 1923, **31**, 269).—An account of the
early development of fused quartz goods manufacture with a
list of German patents.   H. W. H.

235. Heat of Crystallisation of Quartz.   R. C. RAY (*Proc.
Roy. Soc.*, 1922, [*A*], **101**, 509).—The determination of the heat of
crystallisation was carried out by dissolving the quartz in hydro-
fluoric acid and noting the rise of temperature.   The quantity of
material used varied from 3 to 8 gm.   0·3 to 0·6 Gm. of the sand
dissolved, whilst as much as 1·4 gm. of silica glass dissolved, the
temperature in this case rising as much as 34°.   The undissolved
material was washed, dried, and weighed.   Direct determination
of the silica from the solution showed that no loss of silica as silicon

tetrafluoride took place. The size of the silica glass particles was such as to pass mesh 40, while the sand particles passed mesh 20.

The mean of the values of the heats of solution of silica glass was 37·24 kgm.-cals. per gm.-molecule of SiO_2, whilst the mean for silver sand was 30·29 kgm.-cals. per gm.-molecule. Hence the heat of crystallisation of quartz at air temperature could be represented as

$$SiO_2 \text{ (vitreous)} = SiO_2 \text{ (quartz-cryst.)} + 6·95 \text{ kgm.-cals.}$$

This value agreed with that (7·3 kgm.-cals.) calculated by M. W. Travers from results of D. Tschernobaeff, and S. Wologdine.*

Since long grinding of a substance was known to involve the change of at least a portion of it to the vitreous condition, the effect of long grinding on silver sand and glass was studied.

The sand and glass were ground separately for fifteen hours in an agate mortar, and the particles passed a 200-mesh sieve. After drying at 150°, the heats of solution were again determined. The fine substance was entirely dissolved. The mean of the values of the heat of solution of ground silica glass was 36·95 kgm.-cals. per gm.-molecule, whilst the mean value for ground silver sand was 32·46 kgm.-cals. per gm.-molecule. R. Wietzel † found the value for rock crystal, after grinding for one hundred hours, to be 33·65 kgm.-cals.

Hence grinding increased the heat of solution of quartz, some of the material being converted into the vitreous form. No trace of crystalline material was found in the glass used to account for the slight lowering of the heat of solution of the glass on grinding.

The latent heat of crystallisation of quartz was calculated at higher temperatures, and it was shown that near the melting point the heat of crystallisation was almost equal to that at the air temperature.   V. D.

236. Rustless Glass Moulds.   E. A. HAILWOOD, Morley, near Leeds (Brit. Pat., No. **193536**, December 2nd, 1921).—Moulds or forms for shaping or pressing glass are made by forging or rolling up steel or iron, preferably of the kind known as " rustless." Such moulds are for producing ware of finer finish than that produced in moulds of cast metal.   H. G. C.

237. The Lubrication of Glass-making Machinery.   (*Glass Industry*, 1923, **4**, 130).—For plate glass machinery the main problem lay in the polishing machine step bearings, where fine adjustment, continuous operation, and extraordinary weight demanded a film of oil thick enough to act as a protective coating. Only a pure mineral product of the nature of cylinder oil of viscosity about 160″ Saybolt at 210° F. (107° C.) was satisfactory. For the upper or guide bearings, a straight engine oil of about 200″ Saybolt

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* This Journal, TRANS. 1920, **4**, 220.
† *Zeitsch. anorg. Chem.*, 1921, **116**, 75.

viscosity at 100° F. (38° C.) would be satisfactory.   A gear lubricant of 1,000″ Saybolt viscosity at 210° F. (107° C.) would be admirable for driving gearing.   Lubrication of both the grinding and the polishing machinery would have similar requirements.   The usual transportation mechanisms would present two distinct headings (*a*) gears, and (*b*) bearings.   For general bearing lubrication, a good grade of engine oil of viscosity from 200″ to 300″ Saybolt at 100° F. (38° C.) would give satisfactory results.

The vacuum type of bottle machine required a lubricant low in carbon residue, to avoid suction of burned oil and carbon through the headers during the gathering of the glass, which would necessitate frequent cleaning of the valves.   A relatively light-bodied pure mineral product of 150″ to 200″ Saybolt viscosity at 100° F. (38° C.) and extremely low carbon residue content had been found suitable, being generally applied by a force-feed lubricating system to the entire operating system of the machine.   The main spindle was supported by a step bearing, and operated in a bath of the oil, whereas the driving mechanism, which was a reduction gearing, was generally bath lubricated with a fairly heavy straight mineral gear lubricant of about 1,000″ Saybolt viscosity at 210° F. (107° C.). On the top spindle guide-bearing sponge grease or a medium-bodied compression grease was used.   No essential difficulties arose in lubricating a dual table bottle machine.

In window glass factories, the lubrication was really confined to subsidiary operations, and excessive heat was the only abnormal condition.   Where the glass was drawn directly from the melting pot, the operating mechanism must be lubricated with a product of pure petroleum nature with a high flash point and a low degree of evaporation at about 600° F. (327° C.).

Glass pressing machinery was generally arranged to be lubricated automatically or designed to have bath or splash lubrication, and for this a good grade of light engine oil with viscosity 200″ to 300″ Saybolt at 100° F. (38° C.) should be used.   A light-bodied compression cup grease was most suitable for the table carrying the moulds, although some operators preferred to flood the raceway for the ball bearings with a fairly heavy grade of engine oil.   It was now customary to use oil impregnated with air as it entered the machine to lubricate the cylinders and other points which the air touched, including the rotary points when the motive power was air.

Hoists, conveyors, crushers, mixers, air compressors, and blowers, were all parts of a glass house plant which needed lubrication, and special points were that in compressors with crank-case lubrication, a medium non-emulsifiable oil of about 180″ Saybolt viscosity should be used.   For the bearings of blowers a good engine oil of 300″ to 500″ Saybolt viscosity at 100° F. (38° C.) would always be satisfactory.

It was pointed out that, due to the large amount of manual work in the glass industry, and the abnormal conditions under which lubrication had to be carried out, there was a considerable chance of breakdowns due to failure to choose the best lubricant or to apply it properly.   W. S.

238. A Study of the Origin and Cause of Stones in Glass.
HERBERT INSLEY (*J. Amer. Cer. Soc.*, 1923, **6**, 706).—" Stones "
were caused (1) by devitrification of the glass, (2) by undissolved
batch constituents, or (3) by the inclusion in the glass of material
from the refractory walls or crown.

Devitrification stones were caused by the crystallisation of some
constituent of the glass itself.   Difference in the original composition
of the batch probably caused the difference in the kind of crystal
formed.   The most common were *cristobalite, tridymite, wollastonite*
($CaSiO_3$), *diopside* ($CaMg[SiO_3]_2$), and a new sodium–calcium–
silicate.   In glasses of special composition, such as optical glass,
other crystalline compounds were likely to result from devitrification.
Crystals along cords or in layers were due in part to inhomogeneity
in the melt.   Those occurring in large masses or spread uniformly
through the glass were due either to an excess of one constituent
in the batch or to the heat treatment during cooling.

Batch stones were the result of batch constituents or impurities
remaining undissolved in the melt.   The commonest batch stones
were of silica.   Salt-cake (sodium sulphate), when introduced into
the batch in moist lumps, resisted decomposition.   It either rose
to the surface as a scum or remained suspended in the glass.   These
white blotches were distinguished from devitrification spherulites
by their irregular shape.   Frequently foreign materials in the
ingredients, for example, lumps of clay or soil in limestone, were
the cause of batch stones.

Stones, classed either as batch stones or devitrification stones,
occurred also as the result of particles of scum becoming detached
from the main mass of scum.

Crown drops often caused the introduction of crystals of *tridymite*
into the glass when the crowns were mostly made of silica brick.

The most prevalent stones were those produced by the corrosion
of pot or tank walls by the molten glass.   The clay in the inner
walls of pots was usually converted to sillimanite and glass.   Stones
from pot walls were therefore composed of this mixture.   Except
where tank-blocks had been exposed to high temperatures for long
periods of time, the stones caused by the corrosion of tank-blocks
did not show evidence of transformation into sillimanite before
breaking away from the block.   Sometimes there was a surface
transformation after the stone had become embedded in the glass.

Crystals of corundum (Al_2O_3) were found to be no rarity.   The
inside end of a fireclay brick used in the crown of an English tank
furnace had been shown by Wilson to consist of a brown glass full
of thin hexagonal plates of corundum.   Frozen drips on such bricks
were found to consist of glass and corundum.   Corundum crystals
were undoubtedly carried into the glass with drips from fireclay
crown bricks.   These crystals were large (0·2—1 mm.), well-formed,
hexagonal plates, often containing inclusions of glass.   Small
crystals of corundum, associated with fine particles of amorphous
matter and sometimes with normal clay stones in addition, also
occurred in glass.   These probably originated in pot walls or tank-
blocks which contained flint clay carrying hydrated aluminium oxide

nodules. The high temperature caused the nodules to change to corundum before the pieces of clay were floated away in the molten glass. These crystals were small, did not often show well-defined faces and seldom carried inclusions of glass. The elimination of corundum stones was very important, as corundum stones once formed were relatively insoluble in molten glass of the ordinary soda-lime type.

Determinations of the structure and the optical properties of stones by means of the polarising microscope often enabled one to discover the origin and cause of the stones.

The paper was illustrated by photomicrographs of the various types of stone occurring.   E. M. F.

239. The Preparation of Translucent or Opaque Glass by Using Chlorides, Bromides or Sulphates. R. HADDAN, London, and the CORNING GLASS WORKS, Corning, New York, U.S.A. (Brit. Pat., No. **195495**, February 7th, 1922).—A process of making translucent or opaque glass consists in melting a batch containing boric oxide, a relatively high percentage of silica, and a chloride, bromide, or sulphate. Preferably, the boric oxide content of the batch is not less than the alkali content, and the silica is more than 70 per cent. of the ingredients other than the chloride, bromide, or sulphate. In practice, 1 to 5 parts of a chloride, bromide, or sulphate, preferably of an alkali metal, are added to 100 parts of a suitable foundation glass or its batch. The composition of a number of suitable foundation glasses is given in the specification.
H. G. C.

240. A Decoloriser for Borosilicate Glass. R. HADDAN, London, and the CORNING GLASS WORKS, Corning, New York, U.S.A. (Brit. Pat., No. **194888**, February 7th, 1922). See this Journal, ABS. 1923, **7**, 90.—A decoloriser for use with borosilicate glasses consists of neodymium oxide (Nd_2O_3).
H. G. C.

241. A New Glass of High Chemical and Mechanical Resistance. V. HORÁK, Prague, Czecho-Slovakia (Brit. Pat., No. **192713**, February 5th, 1923. Convention date, February 4th, 1922. Not yet accepted).—A resistance glass is made from a batch containing 60—70 per cent. of silica, 15—30 per cent. of boric oxide, 1—2 per cent. of potassium carbonate, 3—6 per cent. of sodium carbonate, 2—6 per cent. of kaolin, up to 4 per cent. of mica, and 1—3 per cent. of an oxide of the silicon group, for example, zirconium or titanium. The glass is stated to have a low coefficient of expansion, a high fusing point, and great resistance to chemical action.   H. G. C.

242. The Effect of Halide Salts on the Colour of Boric Oxide Glasses. R. HADDAN, London, and the CORNING GLASS WORKS, Corning, New York, U.S.A. (Brit. Pat., No. **192919**, February 7th, 1922).—A process of modifying the colours due to metallic salts in

glasses, particularly in the borate glasses coloured by cobalt oxide or nickel oxide, consists in adding a substance or substances containing one or more of the halogens, such as chlorine. As an example of the change, it is stated that when potassium chloride is added to the batch of glass containing a very high proportion of boric oxide and coloured with cobalt oxide, the resultant glass has a green instead of a red colour. The colour change is less noticeable when the proportion of boric oxide in the glass is low or when other halide salts are used instead of the chloride.

H. G. C.

243. Heat Resisting Glasses. W. E. S. TURNER (*J. Roy. Soc. Arts*, 1923, **71**, 401).—An outline of the development of heat-resisting glass. The thermal endurance could be increased by increasing the tensile strength or by reducing the modulus of elasticity and the linear thermal expansion. The first efforts aimed at increasing the tensile strength, by hardening processes such as those of Bastie and of Siemens; then, later, compound glasses were made by Schott, with a layer of glass of low coefficient on the outside, and a layer of higher coefficient inside. These glasses were liable to spontaneous fracture when cold, due to considerable strain; hence they were not a commercial success.

More satisfactory development followed the control of the coefficient of linear expansion of a glass. The two oxides chiefly associated with the low expansion of glasses were silica and boric oxide, the effect of these two being much greater than that of the basic oxides.

The extremely low coefficient of expansion of fused silica enables it to be used even under drastic sudden changes of temperature, but the high temperatures necessary for melting and working this type of glass made the cost of production rather high.

The readily-fused boric oxide, borax, and borates produced low expansion, but when used beyond certain limits, the expansion was seriously increased, and, moreover, the durability of the glass had been found to be lowered considerably. The substitution of boric oxide for silica in a series of soda–borosilicate glasses of constant soda content produced, up to 11 or 12 per cent. boric oxide, an increased durability, then, for higher values, the durability fell rapidly.

The judicious use of silica and boric oxide together produced very satisfactory heat-resisting glasses, including baking and cooking ware, and chemical and illuminating ware. These glasses, being etched but slowly by hydrofluoric acid, generally had to be marked by means of enamel or sand blasting.

The high softening point of these glasses—Pyrex glass softened at 800°, or at 600°, under pressure—and their great mechanical strength promised much wider application.

Further development might conceivably be made by using certain other oxides like zirconia and titania as constituents of glass, but systematic investigations remained yet to be made.

V. D.

244. Heat Absorbing Glass. CHANCE BROS. & CO., LTD., and A. L. FORSTER, Smethwick, Staffordshire (Brit. Pat., No. **197500**, April 11th, 1922).—The specification relates to glass of the kind in which iron oxide is combined in the ferrous state to enable the glass to act as a good absorber of thermal radiation.   According to the invention, the proportion of iron is such that the amount of ferrous oxide per unit area of the glass will give the desired absorption and transmission of thermal and luminous radiations.   For example, hammer scale or iron oxalate is added in such quantity that the finished glass sheet contains about 0·01 of a gram of ferrous oxide per square centimetre of surface.   It is found that with such a glass, the ratio of luminous radiation transmitted to thermal radiation absorbed is a maximum, and the glass is suitable for window and roofing purposes in hot countries.   H. G. C.

245. Tests on the Resistive Qualities of Soda–Lime Glasses to Water. L. A. PALMER (*J. Amer. Cer. Soc.*, 1923, **6**, 579).— The investigations were a continuation of the work already published by A. E. Williams (this Journal, ABS., 1922, **6**, 277), and the method adopted was to treat the articles tested (bottles, tumblers, etc.) to the action of boiling water for six hours.   It was deemed more satisfactory to expose the original, not freshly broken, surfaces to the action of the liquid.   Titrations were made with $0·01N H_2SO_4$ and $0·01N NaOH$, using as indicators either bromothymol blue or phenol red with equally good results.   As a preliminary, before attack, the articles were immersed in or filled with distilled water at the room temperature for twenty-four hours.   The boiling was then conducted, in the case of wide-mouthed articles, in a 2-litre Pyrex beaker covered with a Pyrex flask containing water, the volume of the water in the beaker being kept constant by regular small additions.   Bottles were filled with distilled water, which was brought to boiling, and the bottle placed upright in a bath of $CaCl_2$ solution (b. p. 103·5—104°), the water level in the bottle being maintained by a steam jet.   After treatment, the solutions were titrated in a Pyrex flask, while still hot, with the standard acid until neutral, after which an excess equal to twice the volume already added was run in and the solution boiled for twenty minutes to destroy all carbonates, and a back titration made with the NaOH.   Concordant results on the same make of bottles were obtained, whilst it was found that if a bottle of any particular make gave high results, a second bottle of the same kind gave a relatively high disintegration value when filled with distilled water and stored at the room temperature for six months.   A number of bottles which were subjected to the boiling test were analysed and the solubility numbers found in most cases to be in good agreement with the stability value as calculated from Baillie's modification of the Zulkowski reactivity coefficient, as well as from a second quite empirical formula, namely :

$$\frac{\text{Mol. percentage of } Na_2O}{\text{Mol. percentage of CaO and MgO} + \text{mol. percentage of } Al_2O_3}$$

A. C.

246. The Influence of the Nature of the Glass Surface on the Alternative Modes of Decomposition of Formic Acid.* C. N. HINSHELWOOD and HAROLD HARTLEY (*J. Chem. Soc.*, 1923, **123**, 1333).—Formic acid may be decomposed either into carbon dioxide and hydrogen or into carbon monoxide and water, the extent to which each occurs depending on the temperature, the nature of the surface in contact, and the effect of the products of reaction themselves.

In experiments carried out at 300° in glass vessels, the percentage of carbon dioxide and hydrogen mixture in the total products of complete production was 63—74 with one kind of glass and 16·5—19·1 with another kind. The precise composition of the glasses was not stated but the second was Duroglass.   W. E. S. T.

247. The Relative Action of Acids on Enamel. EMERSON P. POSTE (*J. Amer. Cer. Soc.*, 1923, **6**, 689).—Work was done in the hope of establishing a satisfactory standard test for the resistance of enamels to acid.

Frit tests were run on five different enamels with citric acid solution of varying strength. Graphs representing the results showed that citric acid had the same general characteristic action on the various types of frit.

To show the effect of different lengths of time of action, a pan of about one quart capacity was taken, and 100 c.c. of the acid solution placed in the vessel and allowed to stand one hour. A further 100 c.c. were added then; and also at intervals of 90, 105, 112 and 116 minutes. At 120 minutes, the solution was poured out and the dish rinsed. When dry the successive rings of etching from top downwards showed the effect of 4, 8, 15, 30, 60 and 120 minutes' action, lamp-black vaseline smear being used as indicator. After testing eight different makes of white enamel in this way with 15 per cent. citric acid, it was decided that the full two hours' treatment was necessary to differentiate sharply between the different grades of enamel. It was found, however, that enamelled ware known to be satisfactory in use would be rejected if judged by the first appearance of etching with 15 per cent. citric acid. Moreover, it was evident that etching as detected by this method was not proportional to the time of exposure.

The Bureau of Standards suggested as a tentative test that a solution of 1 per cent. glacial acetic acid and 99 per cent. distilled water at a temperature of 60° to 70° F. be placed in the article and removed hourly. The piece was to be examined for loss of gloss or etching, either of which was considered as indicating failure of the enamel. It was found that 1 per cent. acetic acid was of a suitable strength, but it was impossible for the enameller to get acid of accurate strength from a druggist. 0·15 per cent. citric acid was found to be equivalent in action to 1 per cent. acetic. Its use, however, was not recommended, as errors were likely to occur in making up small amounts of so weak a solution.

* The actual title of the paper is " The Influence of Temperature on Two Alternative Modes of Decomposition of Formic Acid."

A " one minute spot test " was also discussed. A drop of the acid solution was placed on a horizontal surface of the piece, allowed to remain one minute, then wiped with a damp sponge and rubbed lightly with a dry towel. If the enamel had been acted on, a reduction in specular reflection was easily observed at the spot where the acid was applied. One per cent. citric acid was found to affect most of the enamelled cooking utensils on the market, and even 1 per cent. acetic acid had a slight effect on some of the high-priced ware.

The three methods of testing, namely,

A.   One per cent. acetic acid for $1\frac{1}{2}$ hours,
B.   0·15 per cent. citric acid for $1\frac{1}{2}$ hours,
C.   One minute spot test,

were applied to eleven representative samples of commercial ware.

The investigation did not result in establishing a wholly satisfactory test.   E. M. F.

III.—Lamp-worked and General Scientific Apparatus.

248. A New Absorption Bottle for Carbon Dioxide, and Moisture. W. E. MORGAN (*J. Ind. Eng. Chem.*, 1923, **15**, 266).— This bottle, of simple design, is shown in Fig. 119.

When making a determination of carbon dioxide the bottle was
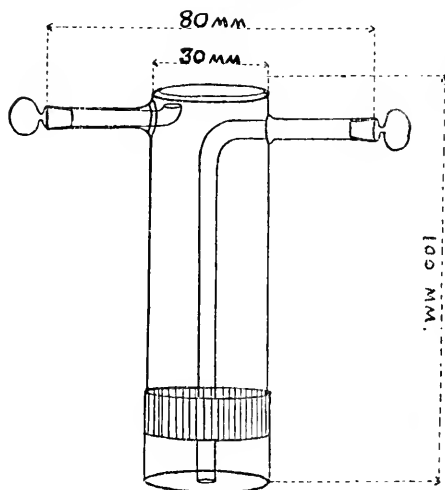
Fig. 119.

set, bottom upwards, on its flat top, and the requisite amount of soda put into it. A cotton or perforated rubber diaphragm was then inserted and the calcium chloride packed in above it. The ground joint at the base was greased, the cup base adjusted, the bottle inverted, and was then ready for use. The gas was led in at the top, and passed out through the long tube embedded in the charge.

Two combustions could be made with one filling. There was no need of ground glass valves to separate the two absorbents, and it was found that there was no migration of water from the soda-lime to the calcium chloride.   V. D.

249. A New Vacuum Manometer. H. RIEGGER (*Zeitsch. Instrumentenkunde*, 1921, **41**, 360).—This instrument was similar in principle to the Knudsen gauge (*Ann. Phys.*, 1914, **44**, 525). In the new form the repelling surface was formed of a vane-shaped disc, *A*, of aluminium suspended by a tungsten wire, over which was a circular heating strip, *B*, 7 mm. broad and 0·006 mm. thick. Rotation was measured by reference to a mark on the glass container and the circular scale, *C*, which, since the distance between the hot and cold surfaces was constant and the turning moment was independent of the " kick," was linear and could be read to several complete revolutions. The whole could be covered by a small furnace and heated to 420°. Damping was achieved by the electromagnets, *D*, and measurements were best carried out ballistically by continuous damping. At low pressures, the calibration curve was linear. The sensitiveness was between 10^{-6} and 10^{-7} mm., and the half period of oscillation was one to one and a half minutes.   M. P.
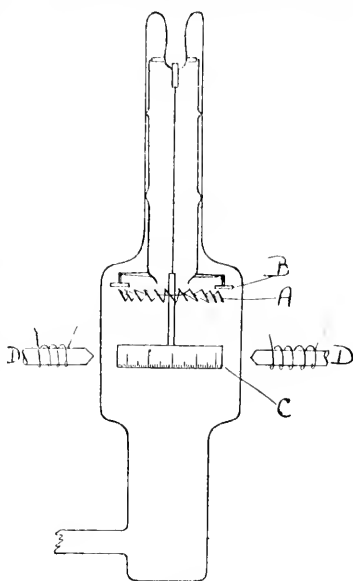
FIG. 120.

250. A Direct Reading Burette. ALBERT M. JACKSON (*J. Opt. Soc. Amer.*, 1923, **7**, 491).—The device permitted the use of an
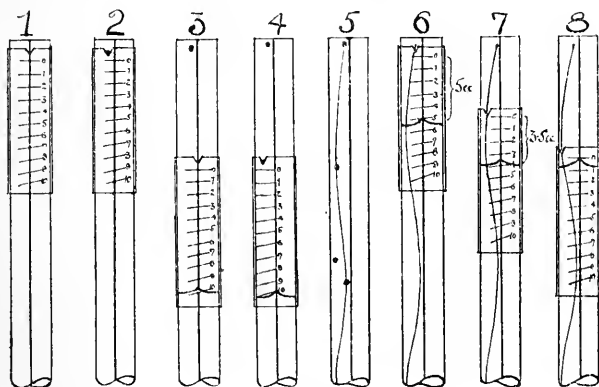
FIG. 121.

ungraduated 50 c.c. burette with blue shellback stripe to give direct readings on successive small titrations. The burette was first

calibrated by letting out 10 c.c. of water by weight from the top zero and noting the linear distance on the burette occupied by that volume. This was then repeated until the 50 c.c. had been discharged. The maximum and minimum distances were then laid out side by side about half an inch apart as in the second figure and the lines joining their contiguous extremities produced to intersect in A. The side BC was then divided into 100 equal parts and each point joined to A. Thus each intercept on the parallel lines BC, DE, represented 0·10 c.c. These converging lines were then marked off on a glass tube with a notch on its upper end which was a sliding fit over the burette tube, and a metal split ring, F, placed on the latter to support the slide. With the slide in position so that its zero line was at the level of the liquid, 1, 10 c.c. by weight were let out. The slide was turned on the metal cap without disturbing the vertical adjustment of the latter, so that the 10 c.c. mark registered with the level of the liquid. A mark was then made on the burette
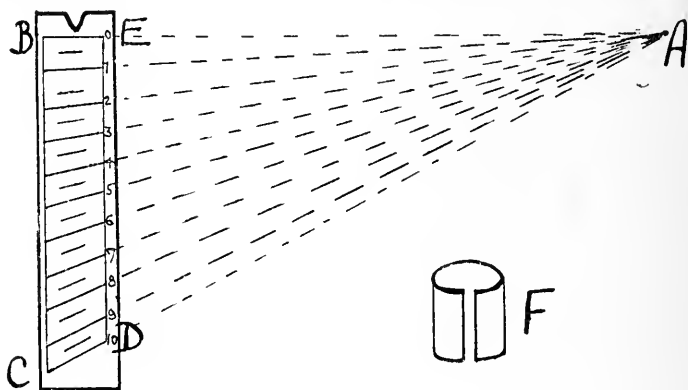
Fig. 122.

corresponding with the position of the notch on the slide, 2. The slide was then lowered so that the zero registered with the level of the liquid, 3, 10 c.c. were let out and the slide turned again so that the 10 c.c. mark coincided with the burette level, and another mark made on the burette in notch 4. This was repeated until the whole 50 c.c. had been discharged, giving 5 correction spots on the burette, which were then joined to give a correction line, 5. In use, the slide was adjusted with the zero at the liquid level, the titration completed, and the slide rotated until the notch coincided with the correcting line. The amount discharged was read from the intersection of the burette level with the graduation marks on the slide, for example, in 6, the reading was 5·0 c.c. The slide was then moved down the burette until the zero was at the liquid level, turned until the notch coincided with the correction line and another test was made, for example, in 7, the reading is 3·5 c.c. The burette was shown set for the next titration in 8. The impossibility of graduating the slide with parallel lines was obvious when it was known that

the distance between the 0 and 10 c.c. marks might differ from that between, say, the 40 and 50 c.c. marks by as much as 0·20 c.c.

M. P.

251. A High Temperature Regulator for Use with Alternating Current. H. S. ROBERTS (*J. Opt. Soc. Amer.*, 1922, **6**, 965).— This paper extended the use of the apparatus already described (this Journal, ABS., 1922, **6**, 38) to alternating current with the possible advantage that leakages from the heating circuit would not affect the thermo couple readings at high temperatures to such an extent as with direct current. The apparatus was essentially the same as before, save that a more efficient main relay had been developed and that a simple rectifier was placed in the galvanometer circuit. This rectifier, *B*, consisted of a reed of clockspring clamped at one end and passing through a coil of about 1500 turns of No. 36 B. & S. gauge copper wire wound on an insulating bobbin. The free end of the reed oscillated between the poles of a permanent magnet. The coil, taking current from the line supply, induced an alternating magnetic field in the reed causing it to oscillate in the field of the magnet with a pitch equal to the line frequency and hence to make contact alternately with the studs, *x*, *y*, on either side. The *E.M.F.* to
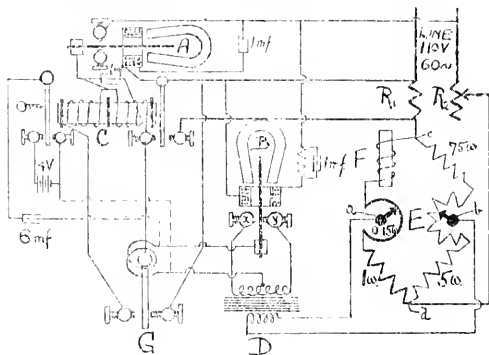
FIG. 123.

be rectified was that of the split secondary from the transformer, *D*, and the result was a pulsating direct current through the galvanometer. The transformer should be of the " core " rather than the " shell " type, as the former was much less affected by stray magnetic fields from the rest of the apparatus. Since the resistance of the primary circuit of the transformer was not low compared with its reactance the phase of the secondary current leads on that of the primary, and this was remedied by inserting a condenser and parallel resistance, R_3, in series with the magnetising coil, the phase being adjusted by varying the amount of parallel resistance. The main relay was operated by direct current from rectifier *A* (which worked satisfactorily with a condenser in parallel and no transformer) and consisted of a converted " main-line " telegraph relay of two spools of 20,000 turns each No. 40 B. & S. copper wire on each leg, having a resistance of 11,000 ohms. The right-hand armature spring should be adjusted so that there was considerable pressure on the right-hand stud when the relay was open. The relay was suitable for currents up to 10 amperes at 40 volts. For heavier currents, for currents through the furnace

of more than 10 amperes, or for lengthy periods of operation un-attended, a second, more robust, relay should be used to break the heating current. As before, the heating element should have a high temperature coefficient of resistance, for example, copper and iron at low temperatures, nickel up to 500°, " alumel " possibly up to 800° and at higher temperatures, platinum. The resistances were preferably wound with no iron in their components, and need not be non-inductive, but should be of low temperature coefficient of resistance, for example, manganin or constantan. The coarse adjustment should be of " dial " construction with studs to which were connected resistance coils rather than of sliding form where the slider made contact with several wires at once, causing changes in the bridge setting due to variation in contact resistance. The heating device, F, should have 5—17 ohms resistance and the controlling resistance, R, cut in or out by the relay should be 2—6 ohms. The inductive device used to prevent sticking of the galvano-meter contacts in the case of direct current (*loc. cit.*), could not be employed here, so use was made of a 4-volt battery and a condenser, so arranged that as the galvanometer boom made contact there was a momentary kick in the reverse direction, due to the discharge of the condenser. Sticking was usually traceable to dirty contacts.

In performance, the furnace was similar to the one run or direct current. At 1400°, the temperature might fall as much as 10° per day. This fall seemed to be due to changes either in the heating element or in furnace insulation. The same regulator was suitable for use with an oil-bath.   M. P.

252. An Improved Slide Wire Resistance. E. KARRER and A. PORITSKY (*J. Opt. Soc. Amer.*, 1923, **7**, 277).—The novel feature of this apparatus was the sliding contact shown on the right-hand
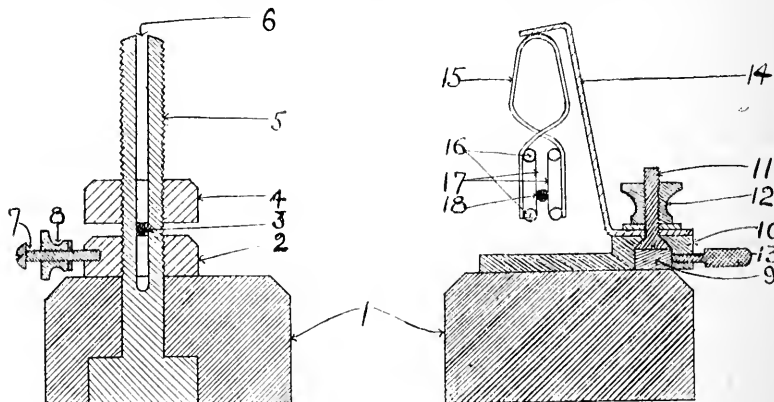
FIG. 124.

half of Fig. 124. The wires, 17, the number and size of which depended on the current to be carried, are wound round and soldered to two cross arms, 16, which in turn are fastened to the

jaws of a phosphor-bronze spring clip, 15, so that the wires, 17, bear on the resister, 18, from opposite directions. A phosphor- bronze strip, 14, carries the current to the binding post, 11, mounted on a metal plate, 10, which slides over the guide, 9, and can be locked in position by the set screw, 13. The left half of the figure shows the arrangement of the binding posts between which the resister is stretched, consisting of the base board, 1, binding post 5, with slot, 6, for resister, 3, a lock nut, 2, clamping screw, 4, and a terminal, 7, 8, for connection to other apparatus. Various kinds of resister could be used, for example, wire as fine as 0·050 mm. diameter or ribbon 2 mm.×12 mm. cross section. When very fine wires are used, they should be of material with low temper- ature coefficient of resistance to minimise errors due to air currents. The apparatus had functioned very trustworthily as branch resistances in Wheatstone bridge assemblies, where ordinary slide wire resistances were quite unsuitable. M. P.

IV.—Decorated Glass.

253. Glass Painting and Mirror Coating. L. SPRINGER (*Glashütte*, 1923, **53**, 164, 179, 195, 211, 227, 243, 259, 275).— Metallic reflections having an iridescent sheen when viewed by incident light were obtained on glass by a variety of yellow etching. Silver, copper, and bismuth compounds were mixed with yellow ochre, with the addition of gum arabic or sugar solution, the mixture was painted on the glass and burnt in, in the muffle, under reducing conditions at a red heat. Various tones were obtained by altering the proportions of the metallic components, excess of copper giving red; of silver, golden; and of bismuth, blue tones. Thus, golden-brown effects were obtained by either of the following : (a) ochre 100, silver nitrate 8, bismuth nitrate (cryst.) 20, copper borate 30; (b) ochre 100, silver nitrate 4, bismuth nitrate 100. A simple method of applying the etch to the surface of the glass was by using it in a very fluid state with a broad brush. After- wards, by shaking the glass and then drying, a very suitable flaky effect was produced. To obtain the maximum play of colour, it was better to paint on first a fluid layer, and, while it was still wet, to go over this with a thicker etch of the same or of different composition. For burning, Muller used an iron muffle of a size 70×40×40 cm., placing in it pieces of coal, asphalt, resin, etc., which, on heating, burned with a reducing flame. By this means one burning was sufficient, but the process could be divided, with one heating to burn in the metal, and a second, in presence of reducing gases, to bring up the colour. A second application of etching compound on the top of the first (when this had been burnt in) was sometimes given, in which case the second etch was generally of different composition from the first, and was not so

strong. A similar effect was also obtained by again burning an etched plate between others containing the etching compound, when the first plate was further attacked by the liberated metallic vapours. For success in coating glass-ware by the above process great care was needed both in the application of the etching compound and in the temperature, duration, and conditions of the heating process. The following errors were possible : A too light metallic layer resulted from insufficient reduction, whilst a too dark layer was obtained by over-reduction. A weakly blue colour without metallic sheen was caused by too low a temperature. The use of glasses of high lime content as well as a prolonged heating period tended to cause devitrification of the glass with resultant opalescence.

The article also described the usual processes for the production of lustre and iridescence on glass and for silvering and gilding.

A. C.

254. Painted Decorations on Matt Glass. (*Diamant*, 1923, **45**, 177).—On the rough face of a matt ground article of glassware, the contour of the decoration was painted with good, bright copal varnish, using the finest possible lines. The ground of the ornamentation was then rapidly and evenly filled in with the same varnish.

The high lights were afterwards painted in with a mixture of copal varnish with one-third its amount of white wax dissolved in turpentine. By the addition of more or less wax a more or less bright light was obtained, two or more such variations giving the same effect as with etching. The durability was determined by the quality of the varnish, which held extraordinarily tenaciously to the matt surface of the glass. Such decorated glass withstood washing with water as well as any other varnished article, but it could not be used for external objects. A. C.

255. The Matt Etching of Glass Plates by the Sand Blast. (*Diamant*, 1923, **45**, 177).—A suitable resist for this purpose was made by soaking 50 gm. of gelatin in water and adding to it zinc chloride solution. When the gelatin was completely dissolved 50 c.c. of glycerine at 30° were added and 225 gm. of lampblack mixed in, the mixture then being allowed to stand. This rubber-like mixture withstood the sand blast but dissolved in water.

A. C.

256. The Acid-polishing of Glass. O. PARKERT (*Diamant*, 1923, **45**, 165, 177).—A bath usually employed for acid-polishing in northern Bohemia was stated to consist of 1 part of water, 2 parts of sulphuric acid, and 1 part of hydrofluoric acid. The amounts were dependent on the concentration of the hydrofluoric acid, and if a test piece was not well polished in thirty seconds further addition of this acid was necessary. Before acid-polishing, it was advantageous to remove cutting scratches from the ware by means of a wooden polishing wheel. Then followed an immersion in the cleaning bath, usually composed of 1,000 parts of water,

12 parts of sulphuric acid and 1 part of hydrochloric acid. The ware was rinsed several times with water and afterwards dipped, by means of wooden tongs, into the polishing bath, which was kept at a temperature of 40—50°. After forty-five seconds' exposure to the acid the article was removed, placed in a bath of water at 35°, and finally cooled in pure water, when it was examined, and, if necessary, repolished. Fine ware had a further polishing on a felt wheel with tin oxide. A. C.

257. Fluosilicic Acid. The Maximum Concentration of the Acid at Room Temperatures. C. A. JACOBSON (*J. Phys. Chem.*, 1923, **27**, 577).—The acid was prepared by treating one part of the purest fluorspar and two parts of precipitated silica with six to eight parts of concentrated H_2SO_4. The resulting vapours were passed through tubes packed with glass wool in order to remove any hydrofluoric acid, then the vapours were passed into water in a five-litre flask, the end of the delivery tube ending under mercury in a cup at the bottom of the flask.

The strength of the acid was determined by a modification of the method of J. Katz.* The reactions which were assumed to take place in the formation of the acid were as represented by the following equations :

$$3SiF_4 + 4H_2O = 2H_2SiF_6 + H_4SiO_4 \quad . \quad . \quad . \quad . \quad . \quad (1)$$
$$SiF_4 + 3H_2O = H_2SiO_3 + 4HF \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$
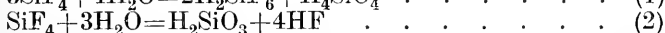
This reaction (2) was regarded as of negligible importance, and if any hydrofluoric acid had been formed, it would have been changed into H_2SiF_6, as in equations (3), (4), and (5).

$$2SiF_4 + 4HF = 2H_2SiF_6 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$
$$4HF + SiO_2 = SiF_4 + 2H_2O \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This SiF_4 was then acted on as in equation (1), or,

$$12HF + 3SiO_2 = 2H_2SiF_6 + H_4SiO_4 + 2H_2O. \qquad (5)$$
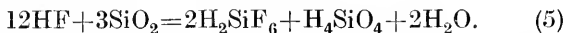
E. Baur † found no hydrofluoric acid in a 30 per cent. solution of H_2SiF_6, and the author used glass apparatus with satisfactory results, detecting no trace of hydrofluoric acid in the two-phase titration method of estimation.

The H_2SiF_6 was found to be about 4 per cent. in the first run. The silica was allowed to settle, the clear liquid was syphoned off, and the process was repeated. By means of successive runs, the concentration of the acid reached 25 per cent. This was eventually raised to 40—45 per cent. by distillation under diminished pressure, at room temperature, a small stream of air being admitted to the distilling liquid, and by further slow distillation over a period of fifteen days acid of approximately 61 per cent. concentration was obtained. V. D.

* *Chem. Zeitung*, 1904, **28**, 356.   † *Ber.*, 1903, **36**, 4209.

V.—Optics and Optical Instruments.

258. Spherical Aberration in Thin Lenses. T. T. SMITH (*Bureau of Standards U.S.A. Scientific Paper No.* 461, from *J. Franklin Inst.*, 1923, **195**, 252).—An elementary theory of the spherical aberration in thin lenses was given, in order to determine readily the aberration of any thin lens for any position of the object, and to give the conditions under which the aberration of two thin lenses would compensate one another, in the case of lenses close together. The subject was treated analytically and, in part, graphically. A graphical solution was given to the problem as to the conditions under which a two-piece lens might be achromatic, free from axial spherical aberration, cemented, and free from coma. The shapes of the lenses necessary to fulfil these conditions were shown. The effect of slight change in the lens shape was indicated.   V. D.

VI.—Illumination and Illuminating Ware.

VII.—Fuels, Refractories, and Furnaces.

259. The Thermal Efficiencies of Production of Different Grades of Gas. A. PARKER (*J. Soc. Chem. Ind.*, 1923, **42**, 111T). —A survey of the method of working a steam-blown illuminating-gas plant, a blue water-gas plant, and a carburetted water-gas plant, with an outline of results of thermal efficiency measurements carried out on them.   A. C.

260. Gas Cleaning with the Cottrell Electrical Precipitation Process. ROY U. WOOD (*Glass Industry*, 1923, **4**, 106).— The simplest arrangement was described as a wire suspended in the axial centre of a pipe, but insulated from it, and connected to a source of direct current at high potential. The pipe being earthed, would act as the deposition electrode, so that if a liquid was deposited it would drain down the pipe almost as quickly as it was deposited, whereas cinders and coke would have to be removed by concussion when the electricity and gas supplies had been cut off. A method had been devised whereby the pipes could be scraped mechanically without interruption of operations.

Advantageous results were obtained with an installation operating on cold producer gas. The gas from five Morgan producers after passing through primary scrubbers, Ernst washer, and baffle drier, contained 0·2 to 0·3 grain of tar per cubic foot, and at that point the Cottrell precipitation reduced it to 0·01 (average 0·005 grain) grain per cubic foot at 16° and 30″ mercury. The operat-

ing cost was about $1·45 per million cubic feet of gas cleaned, when the production was between five and six million cubic feet per twenty-four hours. For small, special-type gas producers, installation costs would vary from $50·00 to $200·00 per thousand cubic feet per hour capacity, with a liquid tar being precipitated; but an automatic scraping device would cost more.

No installations had been made on hot producer gas, but sulphur dioxide gases for chamber sulphuric acid manufacture had been cleaned satisfactorily up to 650° to eliminate cinders, and iron blast furnace gas had been similarly dealt with before its use in boilers and stoves.

The following advantages were claimed by the manufacturers in favour of the apparatus : (1) Low power consumption, (2) Uniform and very low back pressure on the apparatus, (3) Practically no labour, (4) Low repair costs, (5) High efficiency of cleaning, (6) Continuous operation, (7) More uniform and better product obtained.

W. S.

261. The Value of Gas Analysis in Glass Factories. (*Sprech-saal*, 1923, **56**, 218, 228).—A high carbon dioxide content of producer gas indicated generally an incorrect reducing zone in the fuel bed, or burning of the gas in the producer. The former was caused by too shallow a fuel-bed or excessive intervals between charging. Combustion in the producer resulted largely from irregularity of blast distribution through the bed due to clinkering, balling together of fine fuel, or bad distribution at the outer edge of the fuel-bed. Too much care could not be given to watching the surface of the bed and covering over any places burned through. Excess steam in the blast also tended to give too high a CO_2 value, and although in this case the heating power of the gas was greater, due to a larger hydrogen content, the high cost of steam production rendered the gas uneconomical. Analysis not only indicated how closely the average composition of the gas approached that of efficient working, but if it were performed regularly it detected irregularities in the running of the producer, such as unreasonable periods between ash removal, excessive individual charges of fuel, and variations of blast pressure. The analysis was best performed by an automatic CO_2-recorder. The value of producer gas was largely dependent on the lowness of its moisture content, the amount of which was not obtained by ordinary gas analysis, but required some form of hygrometer. Moisture appreciably lowered the flame temperature and increased the cost of firing, whilst it further tended to prevent thorough mixing of the gas and air, the longer duration of combustion so produced increasing the conduction and radiation losses materially. Normal moisture values of producer gas were (*a*) from coal 30 to 60 gm. per cubic m. of dry gas at N.T.P., (*b*) from lignite briquettes 75 to 150 gm., (*c*) from lignite 180 to 400 gm. Causes of high moisture content were the use of moist fuel or of large amounts of steam in the blast, whilst irregular charging of the producer would periodically give the same result.

Analysis of waste gas at the exit ports gave an indication of the completeness of combustion and of the amount of excess air. With combustion complete, the waste gas should consist of CO_2, O_2, and N_2 only, a result secured by the use of excess air (10 to 25 per cent.). Beyond a certain excess, increase of the amount of air resulted in a lowering of the flame temperature. In the case of complete combustion, the ratio of air theoretically needed to air actually used was given by $(P_N - \frac{79}{21}P_0) : P_0$ where P_N and P_0 were the percentages of nitrogen and oxygen, respectively, in the waste gas. With incomplete combustion, the value could only be found after deducting the amount of oxygen required for the combustibles still remaining (CO, H_2, CH_4, etc.).

At the outlet ports, the gas usually contained 15 to 18 per cent. of CO_2 and 6 to 1 per cent. of oxygen. The efficiency of the furnace combustion could not be judged by the CO_2 content of the exit gas alone, since a high CO_2 value would be obtained with some deficit of air, but it could be gathered by a comparison of the CO_2 value with that of the CO, H_2, and O_2. Waste gas containing combustible gases meant a loss of heat, since if these burned in the regenerators, the heat so released could only be saved by raising the producer gas and air to undesirable temperatures. Finally, by taking the CO_2 value of the gas at the exit ports, in the chambers, at the valves, and at other places, any leaky walls, etc., could be detected.   A. C.

262. Recent Developments in Gas Producers. T. R. Wollaston (*J. Soc. Chem. Ind.*, 1923, **42**, 200T).—The following three axioms had proved useful in the improvement of gas producers, namely : (1) Coke was always a good producer fuel. There was enough heat in the gas leaving a producer to coke, or at least to semi-coke, incoming fuel, and when there was direct contact between gas and fuel volatile constituents of the latter enriched the former. In this case, the issuing gas was considerably cooled, whilst coke, or semi-coke only, reached the producer. (2) High blast saturation in older recovery producers was used to reduce the temperature of the combustion zones, to avoid decomposition of ammonia, and to prevent the formation of clinker. This moderation of temperature was obtained equally as well by useful radiation as by direct contact, in which case the radiated heat was sufficient to raise all the steam necessary. (3) The water bottom type of producer was the best and the cheapest. Mechanical and controllable discharge of ash was economical, particularly the hydraulic collection and discharge of large volumes of ash. The 9 foot producer plant, the construction of which was guided by the above principles, had an outlet pipe which first rose vertically above the producer body in the form of a retort, and from the upper end of it a horizontal pipe led away the gas. At the top of the retort was a mechanical feed-hopper, gear controlled, and supplied with fuel from an elevator. The fuel thus passed slowly down the retort, and was kept open and in contact with the outgoing producer gas at a temperature of about 500°, and for a period

of forty-five minutes. The coked fuel was then symmetrically spread in the producer, which had no refractory lining, but was surrounded by an annular jacket used as a steam boiler or water-heater. A central cone in the producer reached to the surface of the fuel, and into this was introduced the blast pipe with a controllable water atomiser. The blast thus passed to the top of the cone and down again before entering the fuel bed, being so superheated and abstracting heat from the combustion zones. Blast distribution was secured by a standard Duff type grate, whilst crusher rolls in the ash bed, simply regulated, gave perfect control of the bed. The crushed ash was discharged to the water lute and driven from this to a central sump by means of a circulated water current, being elevated and discharged without hand labour.

This producer gave in six months' running an average gasification of 18 lb. per sq. ft. per hour, the gas exceeding 125,000 cub. ft. per ton of common ungraded slacks (11,500 B.Th.U. per lb.). The producer was excellent for ammonia and tar recovery without the use of a large excess of steam, and gave a gas singularly free from dust.   A. C.

263. Gas Producer Practice, and a Standard Method for Making Heat Balances. W. B. CHAPMAN (*Glass Industry*, 1923, **4**, 123).—The author had been greatly impressed by a paper entitled " Gas Producer Practice in Steel Works," by Waldemar Dyrssen, read before the American Iron and Steel Institute, May 25th, 1923. The term " gasifying temperature," however, was rather difficult to understand, especially as at the lowest point of the fire-bed in a producer the carbon burnt to CO_2, which was cooled during its passage up the fire and carbonised to CO. Since the so-called " gasification temperature " evidently referred to the decomposition zone, it would depend on the thickness of the bed, and on the temperature at the base; but a number of experiments carried out on various producers might establish some definite relation between the highest temperature in the producer and the arbitrary temperature. Some practical way must be found also for making allowance for the blow-holes which exist in practice. It was agreed that a recording thermometer at the gas outlet was the greatest aid in operating a producer—but the best producer gas seen by the author was made at a plant where a bonus was paid to the man who made the highest percentage of CO. It was suggested that a recording thermometer be used, and the men paid a slight bonus for keeping the temperature of the outgoing gas between defined maximum and minimum points.

Whereas individuals had drawn up fairly complete heat balances for isolated tests, it was considered worth while to appoint a committee to establish a standard method for making heat balances; and the results of twelve different tests on the Hughes, the Morgan, the Wood, and the Chapman producers were taken, a mean being selected as typical of first class practice. Of the energy put into the producer $97\frac{1}{2}$ per cent. was in the form of coal, and $2\frac{1}{2}$ per cent. in the form of steam; $74\frac{1}{2}$ per cent. was utilised if cold producer

gas was the fuel (86 per cent. if the sensible heat in the gas was included).   Of the 14 per cent. lost, 12 per cent. was due to radiation, 1 per cent. due to carbon in the soot, 1 per cent. due to the cooling water and $\frac{1}{2}$ per cent. due to carbon in the ashes.

In most producer practice, the outgoing gases might be run at a lower temperature, thus saving as much as 5 per cent. due to cutting down radiation losses.   This might be carried out by putting on sufficient coal to make the fire-bed thick and thus cool the gas as low as 1,200° F. (650° C), provided there were no blow-holes.   The bottom of the producer should be as hot as possible consistent with leaving the ash unfused.

The necessity of horizontal uniformity was re-emphasised, and it was pointed out that uneven removal of ashes caused irregularities in temperature and density.   Mr. Dyrssen and the author were both advocates of the continuous agitation of the ash zone.

A summary of the Heat Balance was given, and also the method of arriving at the figures :

Average Analysis of Gas.

CO_2	O_2	CO	C_2H_4	H_2	CH_4	N_2	B.T.U.
4·8	0·2	25·5	0·4	12·1	3·6	53·4	154·0

Total per cent. combustibles in gas .... 41·6
Average coal fed per hour .... 2,816 lb.
Average duration of tests .... 72 hours
Fuel, mostly gas-coal from Pittsburgh district.

Average Analysis of Coal as fired.

Moisture.	Volatiles.	Fixed carbon.	Ash.	Sulphur in ash.	Total carbon.	B.T.U.
3·5	32·8	56·2	7·5	1·1	74·8	134·50

Heat Balance (Summary).

Dr.   B.T.U.

	B.T.U.		
B.T.U. per lb. coal as fired	13,450	=	97·5%
Sensible heat of coal @ 62° F.	0	=	0·0
,, ,, ,, steam above 62° F.	350	=	2·5
,, ,, ,, air ,, ,, ...	0	=	0·0
	13,800		100·0%

Cr.   B.T.U.

	B.T.U.		
Calculated power of gas	10,296·4	=	74·61%
Sensible heat of gas	1,575·9	=	11·42
Losses—			
Unburned carbon in ash	47·8	=	0·34
,, ,, ,, soot	133·4	=	0·97
(Assumed 1% coal fired)			
Sensible heat of ash 80° F.	0·3	=	0·00
,, ,, ,, cooling water	133·5	=	0·97
Radiation, etc. (by difference)	1,612·7	=	11·69
	13,800·0	=	100·00%
Total losses			13·97%

Efficiency of producer (hot gas)	86·03%
„ „ „ (cold gas)	74·61%
Coal gasified per sq. ft. per hour	35·85 lb.
Steam used per lb. of coal	0·304 lb.
Gas per lb. of coal as fired	66·86 cu. ft.
Air „ „ „ „ „ „	3·00 lb.
Cooling water per lb. of coal as fired	1·78 lb.
Temperature of gas leaving producer (average 1,250° F.)	677° C.

Producers equipped with 4- or 5-stage blowers with $\frac{9}{16}''$ nozzle or with steam turbo blowers.

W. S.

264. Tentative Specifications for Glass House Refractories. (A DISCUSSION) (*Bull. Amer. Cer. Soc.*, 1923, **2**, 29).—After two and a half years of study of the subject the Committee of the American Ceramic Society drew up the following report *which was not accepted*, however, as providing entirely satisfactory specifications. The report, which was circulated for study, was as follows :

Introduction.

The effort of this committee has been to develop a set of specifications that will aid the consumer in getting what he needs, and then obtaining the most service from what he gets, and at the same time be a guide to the manufacturer in supplying it, without working a hardship on either. We believe that such a set of specifications, when ultimately worked out with proper limits, should even be an aid to the manufacturer in producing better grades of refractory wares.

Our aim has been to obtain limits that actually apply to the wares as now made; where possible pointing the way to better practice; and where it is necessary to apply tests, have them of such a nature that the results will distinguish clearly between satisfactory and unsatisfactory products. At the same time, knowing that a large percentage of the plants manufacturing and using these products are still unequipped with laboratories, it has been our aim to have all tests so arranged that they can be applied on any plant without special laboratory equipment. This has been done to permit of ready application of the specifications under existing conditions.

In so far as they apply the committee has endeavoured to use the A.S.T.M. specifications for refractories, notably the reports of Committee C-8. However, there are several requirements that are essential to refractories used in the glass industries, that are of minor importance to refractories used in other industries. Hence it has been necessary to devise several more or less new tests. These have been worked out by observing the peculiarities of the various wares in service, and then selecting from the mass of laboratory tests on hand, those which most clearly delimit (prescribe the limits of) the particular requirements under consideration.

The specifications herein set forth are of necessity of a tentative nature. We believe that the general plan will prove satisfactory, but that a great deal of thought must yet be given to the subject, and considerable more data be collected relative to proper limits,

etc.; before these tentative specifications can all be accepted as standard.

Many of the limits are already quite well established, while others need considerable more weight of evidence.

Heat treatments are expressed in cone numbers, the temperature measuring instrument being depended upon merely to indicate the progress of the furnace. It is preferable however to use accurately calibrated instruments and record exact temperatures in addition to the cone numbers.

An effort has been made to correlate all the tests and their limits, so that one specification will not conflict with another.

It appears very desirable to have a hot bending test for pot clay at glass melting temperatures, which in a measure at least will correspond to the bulging of pot walls. It also appears desirable to have a test which in a measure corresponds to the shrinkage that takes place in the pot while it is in the pot arch, and the additional shrinkage which must take place before the pot can be considered to be in a satisfactory condition for use.

The limits, etc., of the load test have been so thoroughly worked out that we believe there will be no need to alter them in the future. Hence, the results of such tests may well form a basis for correlation of other tests. I (b) and (d) have been worked out for use in lieu of the load test, where a load test is not available.

Under Clay Refractory Blocks and Bricks, for Class A materials, the limits correspond with those usually used for first grade clay refractories, while for Class B materials, the limits include what are generally considered as second or third grade Clay Refractories. The limits of this test have been quite thoroughly worked out and correlated with results of the load test.

The limits, etc., for the hot bending tests and for volume change of pot clay during firing are not as thoroughly worked out as we hope to see them later.

Specifications.

I. *Clay Refractory Blocks and Brick.*

A. Materials which are intended to be exposed to the direct heat of the furnace and be either subject to the action of dust or not, but not to be in contact with the glass itself.

(a) These materials [cut to the form of standard nine (9) inch brick] when subjected to a load of forty (40) pounds per square inch, and heated as follows, in the usual form of load test furnace.*

Time.	Temp.°	Time.	Temp.°
0 hr.	0·0	$3\frac{1}{2}$ hrs.	1270
$\frac{1}{2}$,,	370·0	4 ,,	1320
1 ,,	670	$4\frac{1}{2}$,,	1350
$1\frac{1}{2}$ hrs.	880	5 ,,	1350
2 ,,	1020	$5\frac{1}{2}$,.	1350
$2\frac{1}{2}$,,	1120	6 .,	1350
3 .,	1200		

* U.S. Bureau of Standards, Tech. Paper No. 7.

Bricks so tested shall not yield in compression more than
4 per cent. (measurement to be made on cold brick after
test).

(b) In the case of aluminous material the softening
point * must not be less than that of cone 31 and pieces
cut (or moulded) to form standard nine (9) inch brick,
on being heated to 1,400° C. (2,555° F.) in four (4) hours
and held at that temperature for five (5) hours, shall not
expand more than one (1) per cent., nor contract more
than one and one-half (1·5) per cent. linear. Not many
people keep their thermocouples accurately calibrated,
hence in lieu of the above test we suggest that cone 15 be
brought down in four (4) hours and that this temperature
be maintained for five (5) hours by means of a thermo-
couple which will indicate the true temperature.

In the case of siliceous brick the softening point may
be as low as cone 28, provided the compression in the load
test, as described above, is less than three (3) per cent.

(c) Bars $3 \times 1\frac{1}{2} \times 12$ inches made of the raw refractory
batch and fired in a commercial kiln with refractory blocks,
when supported on knife edges (10 inch span) loaded at
the centre (M=10 pounds per square inch) and heated in
a test kiln to cone 15 (as in IV (b) below) shall not sag,
on the under side, more than $\frac{1}{2}$ inch below the knife edges.

B. Clay refractories which are not directly exposed to fire
or glass attach (such as materials used in backing up).

(d) These clay refractories should have softening points
between cones 26 and 31. The limits shall be the same
as for first grade refractories above when a standard nine
(9) inch brick sized piece is heated to 1,270° C. (cone 12)
in four (4) hours and held at that temperature for five
(5) hours.

In lieu of a calibrated thermocouple we suggest that
cone 12 be brought down in four (4) hours and that this
temperature be maintained for five (5) hours.

(e) The dimensions of all materials in A and B must
not vary more than $\frac{3}{16}''$ per foot from specified dimensions.
Bricks and blocks in both classes must be reasonably well
made and correspondingly free from drying and burn-
ing defects, such as cracking, warpage and improper
oxidation.

II. *Silica Refractories.*

(a) Silica brick and tile should have a good ring.

(b) In order to insure satisfactory quartz, cristobalite,
tridymite relations, the specific gravity † should not be over
2·38 for brick made from Medina quartzite, nor more than
2·42 for brick made from Baraboo quartzite.

* See method of No. 1 below.   † See method 2 below.

(c) The effective modulus * of rupture of standard nine (9) inch brick, set on edge on knife edges [six (6) inch span] should not be less than 500 lb. per square inch.

(d) The " softening point " shall not be less than that of cone 31.

III. *Flux Blocks.*

(a) The " softening point " determined on cones made from a ground sample (60 mesh) of the block, shall not be less than that of cone 29.

(b) The porosity † of tank-blocks shall not be over 25 per cent.

(c) Crucibles made of the raw flux block mixture, in a mould as per the accompanying sketch, fired in a commercial kiln with flux blocks (or optional to cone 12 in a test furnace in 6 hours and held one and one-half hours) and subjected to a three-day fluxing test at the temperature and with the glass (cullet) against which the blocks are to be used, shall show but little attack. The amount of attack can be observed either by cooling the crucible with the glass in it and splitting the crucible vertically through its centre, or by pouring the hot glass and inverting the crucible in the furnace for a few minutes to drain. It can then be studied without being broken.

(d) The porosity of $2\frac{1}{2}$ inch cubes cut from fired blocks and reheated in a test kiln [1,400° C. in 6 hours (2,555° F.) and held at that temperature for one and a half (1·5) hours] shall not have a porosity greater than 22 per cent. nor less than 12 per cent. The volume change determined by suspended weight method ‡ shall not exceed 6 per cent., nor be more than 1 per cent. expansion. In lieu of a standardised thermo element, we suggest cone 15 in six (6) hours and that this temperature be maintained for one and one-half (1·5) hours.

(e) The requirements for dimensions, etc., shall be the same as for I (e). Rectangular blocks shall be truly so and not merely have opposite sides parallel.

IV. *Glass Melting Pots.*

(a) The softening point § determined from cones made of the raw pot mix, when ground to pass a 65-mesh sieve, shall not be less than that of cone 30, and the softening point of any individual plastic clay constituents of the mix, similarly treated shall not be less than that of cone 29.

(b) Bars $1 \times 1 \times 7$ inches made from raw pot body, and fired in a test furnace to cone 15 [cone 15 in six (6) hours and held at this temperature for one and one-half (1·5) hours] when supported on knife edges [five (5) inch span] loaded at the centre (M=7 lb. per square inch) and reheated in a test furnace to cone 15 the same as they were the first time, shall not sag (measured on the under side) more than one-half inch below the knife edges.

* See method 3 below.   † See method 4 below.
‡ See method 5 below.   § See method 1 below.

(c) The total shrinkage * of the pot mix from the wet raw
state (consistency of side clay) to the condition after being
fired to cone 14 in a test furnace (cone 14) in six (6) hours and
held at this temperature one and a half (1·5) hours shall not
be over 24 per cent. (approximately) by volume (8·00 per cent.
linear) based on per cent. of wet size. The shrinkage between
cones 4 and 14 (determined on pieces previously burned to
cone 4), when heated same as above, shall not be more than
3·9 per cent. (approximately) by volume (1·3 per cent. linear).
These figures are based on a drying shrinkage of 15 per cent.
(approximately) by volume (5·0 per cent. linear) and a burning
shrinkage to cone 4 of 5·1 per cent. (approximately) by volume
(1·7 per cent. linear).

(d) Bars $1 \times 1 \times 7$ inches made of the raw pot mix, when
dried and broken according to the tentative method of the
A.C.S.† shall not show a modulus of rupture less than 225 lb.
per square inch.

Any material failing in any one test shall be discarded as
unsatisfactory.

Methods of Procedure.

(1) Softening point.—The sample shall be ground to pass through
a sixty-five (65) mesh Tyler Standard screen (0·208 mm. opening)
mixed with water and moulded into cones similar to Seger-Orton
pyrometric cones tetrahedra, 7 mm. along an edge of the base and
30 mm. high. If the sample be non-plastic, a little organic glue
may be added, so that the cones will hold together when dry. The
cones shall be set in a straight line in a plaque. A dried cone of
the sample shall be set in the plaque with not more than two (2)
Orton cones on each side of it. Thus none of the standard cones
need be more than $\frac{3}{4}$ inches away from the material being tested.
The heating shall be done in a gas-fired or other furnace in which
the atmosphere is maintained nearly neutral (not strongly reducing).
The total period of heating shall not be over two (2) hours. The
rate of heating, near the softening point of the material, should not
be greater than that required to cause the bending of one standard
cone in three (3) minutes.

(2) Specific Gravity of Silica Brick.—Two $\frac{1}{2}$-inch cubes of the
dried material are weighed, saturated with water and weighed wet,
then weighed suspended in water. Then in terms of grams and
cubic centimetres the specific gravity $= \dfrac{D}{(W-S)-(W-D)}$ where
$D=$dry weight, $W=$wet weight (saturated weight) and $S=$suspended
weight.

(3) Effective Modulus of Rupture.—The effective modulus of
rupture is obtained by subtracting the average deviation from the
mean modulus of rupture. The average for this figure shall be made
from data on not less than six bricks. The modulus of rupture is

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* See method 5 below.
† Report of Committee on Standards, Jan. 3rd, 1918, pp. 40—43.

calculated by means of the following formula : $R = \dfrac{3WL}{2bd^2}$, where R equals modulus of rupture, L equals distance between supports in inches, b equals breadth of specimen in inches, d equals depth of specimen in inches, and W equals load in pounds at which failure occurs. The mean modulus is merely the arithmetical mean of these figures, and for the effective modulus we have : Effective R = mean $R = \sqrt{\dfrac{S}{N-1}}$, where S equals the sum of the squares of the differences between the various observations and the mean modulus, and N equals the number of observations.

(4) Porosity of Burned Clay Products.—Two $\frac{1}{2}$-inch cubes of the dry material are weighed, saturated with water and weighed wet, then weighed suspended in water. Then, in terms of grams and cubic centimetres, the porosity (ratio of the volume of the open pores to the exterior volume of the piece) $= \dfrac{W-D}{W-S}$, where D=dry weight, W = wet weight (saturated weight), and S=suspended weight.

(5) Volume change by Suspended Weight Method.—Two $\frac{1}{2}$-inch cubes of the material are saturated with water and weighed wet, then suspended in water, after which they are dried and reheated. Saturated and suspended weights of the reheated pieces is taken. The volume change $= 1 - \dfrac{W_2 - S_2}{W_1 - S_1}$, where W=wet weight (saturated weight) before reheating, S=suspended weight before reheating. W=wet weight (saturated weight) after reheating and S=suspended weight after reheating.

If it is desired to measure the change in volume from the raw to the fired state, the pieces may be run in oil both before and after firing. Or, if run in water after firing, the readings in oil must be converted to a water basis by dividing by the specific gravity of the oil as : $\dfrac{W_1 - S_1}{\text{Sp. gr. of oil}}$.

Addendum.

As soon as possible data should be obtained for a heating schedule to be used in heating glass melting tanks. At present we can only suggest the following :

In days 1, 75° C. (167° F.) ; 2, 120° C. (248° F.) ; 3, 234° C. (450° F.) ; then 94° C. (200° F.) per day to 1,250° C. (2,300° F.). In heating window glass tank-blocks for hot repairs the same schedule is suggested to 900° C. (1,657° F.), then hold for thirty-six hours.

The present specifications as far as pots are concerned deal only with the constituents from which the pots are made. It is hoped, however, that we may soon be able to outline a standard method of handling pots by the consumer, and of their preparation for the furnace.

At present we can only suggest that pots, tank-blocks, refractories, etc., stored by consumers be kept above 90° F. (32° C.) at all times.

With pots which have been stored as above, the following heating schedule is suggested.

In days 1, 75° C. (167° F.); 2, 120° C. (248° F.); 3, 371° C. (700° F.); 4, 596° C. (1,110° F.); 5, 816° C. (1,500° F.); 6, 1,025° C. (1,880° F.); 7, 1,160° C. (2,120° F.); (check with cone 4 flat under centre of bottom); hold thirty hours.

The pot arch should be cooled to 32° C. (90° F.) before pots are placed in it. If a pot arch is cold it should be dried out by heating to redness and then cooling to 32° C. (90° F.) before pots are placed in it. Where pots are to be set directly in a pot furnace at time of starting up, the furnace should first be dried out by heating to bright redness and then cooled to 32° C. (90° F.) before the pots are placed in it.

It is essential that the pot arches be constructed so that the bottoms of the pots will be as thoroughly heated as the crowns. Pot arches of the down draught type, with exit flues directly under the centre of the pot, largely aid in obtaining this uniformity of heating throughout the pot. An easily applied check on the uniformity of heating in the pot arch is to place one pat of cones under the centre of the bottom of the pot, and a similar set on top of the crown. Cones 01 to 5 inclusive usually serve for this purpose. It may even be desirable to go much higher than suggested above.

It is desired to establish as soon as possible a fluxing test for pot clay, of the same general nature as that given for flux clay.

DONALD W. ROSS, *Chairman.*
GEORGE A. LOOMIS,
ARTHUR F. GORTON,
C. W. BERRY.

F. W. H.

265. The Requirements of Refractories for Electric Furnaces. CLYDE E. WILLIAMS (*J. Amer. Cer. Soc.*, 1923, **6**, 753).—A discussion of the refractories problems now existing in the important electric furnace processes. It was important that the refractory material should have a high fusing point determined under a load greater than that under which the refractory would be used. It should also have a high heat conductivity, be constant in volume with temperature changes, and be resistant to the action of slags and gases. High electrical conductivity was usually undesirable.

Specific conditions and refractory requirements in steel, iron, and non-ferrous metal melting, smelting furnaces for producing iron, ferro-alloys and calcium carbide and in furnaces for melting refractory materials were discussed. For the melting of alumina, magnesia, spinel, sillimanite, etc., a steel shell was used. This was lined with the material to be melted by cooling the walls to freeze part of the charge.

Clays of high alumina content and higher temperatures of firing had recently been more widely used. Aluminium oxide had been added to fireclay in amounts up to and even greater than the content of sillimanite (Al_2O_3,SiO_2) and had frequently produced very

satisfactory refractories. The presence of excess aluminium oxide increased the fusion temperature and in many cases reduced the corrosion of both slags and gases. Bauxite bricks were giving more satisfaction now that they were being burned at higher temperatures and consequently did not shrink so much in use.

"Super-refractories" were coming into wider use. Silicon carbide was becoming quite common. Fused magnesia was also being used. Fused alumina, sillimanite, spinel ($MgOAl_2O_3$), zircon, and many others were being experimented with and used to some extent in commercial operations. The commercial production of sufficiently high firing temperatures and the difficulty of developing satisfactory bonds was holding back the widespread use of these materials.   E. M. F.

266. Fuel and Refractory Lining Material. HIRSCH (*Ker. Rundschau*, 1923, **31**, 14).—The necessity for the testing of refractory materials before use was emphasised. Particular reference was made to refractory materials for boiler-furnaces where the chemical action of slags was an important factor. The action of slag on refractory material was tested by placing pulverised slag in a cavity cut out of a block of the refractory material and burning the whole at Seger cone 14. The action of the slag was seen by cutting through the test-piece. Eight slags of the following composition were tested with blocks of the same shale.

	No. 1.	2.	3.	4.	5.	6.	7.	8.
Loss on Ignition ...	0·5	4·1	2·6	2·9	—	0·1	—	6·3
SiO_2	47·7	52·3	49·3	45·6	10·8	46·3	17·0	5·8
Al_2O_3	42·9	33·0	31·9	35·5	9·6	6·2	17·2	12·6
Fe_2O_3	3·8	4·9	6·3	3·0	25·5	25·8	15·5	10·0
CaO	4·5	3·5	6·8	6·7	34·6	19·8	40·4	50·6
MgO	0·1	1·8	1·5	3·7	1·6	1·7	4·6	11·2
Alkalies	0·6	—	—	1·2	1·6	0·2	0·2	3·5
SO_3	—	0·3	0·1	0·6	16·4	—	3·9	0·1
S	—	0·1	0·3	0·9	—	—	1·0	—
Cone melting point .	27	17	14	12	10	9	12	11

The first four, which were coal slags, had only a slight corrosive effect. The lignite slags (numbers 5—8) produced corrosion in varying degree, the last showing complete solution of the walls of the cavity.   In the case of powerful slags, the most suitable refractory material was chosen by comparison, by testing the same slag with blocks of different refractory materials.   The densest material was found to be the most resistant to attack.   The action of a slag rich in iron oxide and lime was tried on a shale, first, unprotected, secondly, with a facing of corundum, thirdly, with silicon carbide, and fourthly, with a lining of "dynamidon," a production with more than 70 per cent. of alumina.   The last-named proved most efficient, the slag having no action.

Low density, high alumina content, and high degree of refractoriness (not less than Seger cone 28) were shown to be very necessary properties.   It was also important that the bricks should be uniform and free from flaws. They should have sharp edges, ability to

withstand changes of temperature, a compression resistance of at least 80 kgm. per sq. cm., and an after-shrinkage, when heated to Seger cone 14, of not more than 2 per cent.

The cement used should also be adapted to the slag and the joints should be made as thin as possible. The fire-box of the boiler furnace should be built as big as possible to prevent too strong local heating by the flames, and trouble by deposits of slag.

<div align="right">E. M. F.</div>

267. Studies on Clays. O. BOUDOUARD and J. LEFRANC (*Bull. Soc. chim.*, 1922, **31**, 976, 1145; from *J. Soc. Chem. Ind.*, 1922, **41**, 983A; 1923, **42**, 145A).—The analyses of a number of clays were given and discussed. It was shown that the alkali content of different samples of kaolin varied considerably, also that one sample of *halloysite* contained much calcium.

Examples of the method for obtaining the mineralogical composition of clays by rational analysis and by microscopical examination were given. The former depended on the fact that treatment with sulphuric acid enabled the quartz and felspar to be determined, whilst caustic soda allowed of a distinction being made between *muscovite* and magnesian mica. Inaccurate results were obtained for kaolin and quartz when calcium compounds were present, particularly when these were in the form of *anorthite* or *labradorite*. On the other hand, microscopical examination, coupled with a knowledge of the percentage composition, gave results of sufficient accuracy for most purposes. A. C.

268. Removing Iron Oxide from Clay by Means of Chlorine Gas. Y. ICHIKAWA [Kôgyô-Kwagaku Zasshi (*J. Chem. Ind., Japan*), 1922, **25**, 1310; from *J. Soc. Chem. Ind.*, 1923, **42**, 269A].— Metallic iron reacted with chlorine on heating, the ferric chloride so formed then subliming. By heating a mixture of clay containing 3·13 per cent. of iron as ferric oxide, and charcoal at 100—150° for two hours in a current of dry chlorine gas, 49·04 per cent. of the iron was removed. A. C.

269. The Composition and Microscopical Structure of Clays, their Fusibility and Behaviour at High Temperatures. L. BERTRAND and A. LANQUINE (*Céramique*, 1922, **25**, I, 153; from *J. Soc. Chem. Ind.*, 1922, **41**, 813A. Compare this vol., ABS. No. 175).—From the composition and fusion points of 101 samples of clay it was shown that the refractoriness of the clays was not determined by the alumina content. All clays of more than 30 per cent. of alumina content were refractory, but some with only 8·15 per cent. of alumina fused at 1650° or above. The melting points of four samples with alumina ranging from 16·6 to 21·85 per cent. were between 1270° and 1120°. A. C.

270. The Effect of Grog Additions on the Fire Resistance of Hollow Tile. HARRY D. FOSTER (*J. Amer. Cer. Soc.*, 1923, **6**, 748).—Tests of hollow tile from three different clays each containing 0, 2·5, 5 and 10 per cent. grog were made. The test panel,

<div align="right">13—2</div>

consisting of $8 \times 12 \times 12$ inch six-cell load-bearing tiles formed one side of a furnace and was subjected to a load of 120 lb. per square inch of gross bearing area. Fig. 125 shows the time–temperature reference curve followed during the fire-tests. The period of time which a load-bearing wall was able to carry its load and hold back the fire, and the salvage value of the wall after the fire, or in case fire-resistive interior construction was used, the extent of replacement necessary, served as a criterion of the fire resistance of the panel being tested.
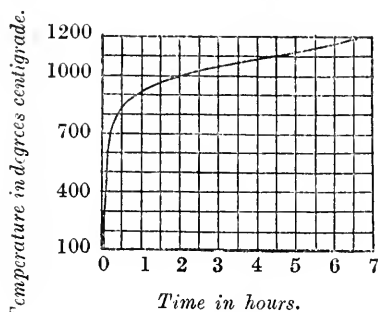
Fig. 125.

The panels of this series were able to carry their load from twenty minutes to six hours or more, as follows :

Percentages of Grog Additions.

	0	2·5	5	10
Shale tile	6 hrs.	6 hrs.	4 hrs. 32 mins.	3 hrs. 47 mins.
Fireclay tile	6 ,,	6 ,,	4 ,, 2 ,,	3 ,, 17 ,,
Shale and fireclay tile		6 ,,	4 ,, 50 ,,	20 ,,

Examination under the microscope of fractures of tile containing grog disclosed very minute cracks probably from drying and burning shrinkage, radiating from the grog particles into the clay matrix. These fine cracks were perhaps responsible for the early cracking of the tile body.

It was concluded that the small grog additions which could be conveniently made in manufacturing practice had no effect, but that additions of 5 per cent. or more would materially decrease the fire resistance of hollow tile.   E. M. F.

271. Burner for Mixture of Air with either Pulverised, Liquid or Gaseous Fuel. (*Chem. Zeitung. Ubersicht*, 1923, **40—42**, 95; D.R.P. 341064. Kl 241 14th March, 1919).—As shown
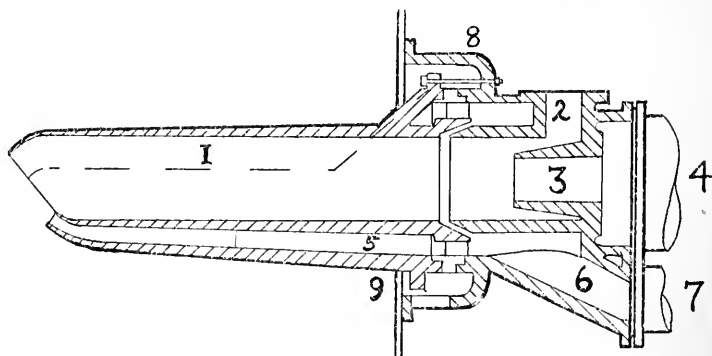
Fig. 126.

in the diagram, Fig. 126, the principal nozzle, 1, was fitted at the rear on to the fuel injector system, which drew air through the pipe, 4, and mouthpiece, 3, the fuel passing in at the connection,2. Although the air stream drew in the fuel, secondary air was drawn into the combustion zone by means of tube, 5, connected by 6 to the air pipe, 7. A case, 8, secured the whole contrivance to the wall, 9, of the furnace by means of screws.   W. S.

272. Critical Discussion of a Glass Furnace.   R. W. MULLER (*Ker. Rundschau*, 1923, **31**, 226).—A 14 pot furnace designed to melt glass in eighteen hours actually took twenty-eight to thirty-six hours. The furnace was heated by gas from two revolving grate producers of 1·5 in. diameter, each giving 25,000 cub. in. of gas per twenty-four hours. The gas left the producers at 700° and its hot gas heating value was 1,480 k. per cub. in. The sensible heat was used to generate the steam for the producers so reducing the heating value to 1,325 k. The gas was then passed through scrubbers which further reduced the value to 1,275 k. It left the scrubbers at 40 mm. W.G. and was boosted up to 300 mm. W.G. by a fan, passing through a main flue of 200 mm. cross section and thence into 14 branch flues of 80 mm. cross section. The author considered that the gas should have been used hot and part of it employed to generate the steam as was done by Bänder and Främbs at Hagen.

Each pot had its own recuperator and firing. The waste gases entered the recuperators at 1,250°, and, as the recuperators were too small, left them at 600°. The secondary air was only heated at about 500°. The composition of the producer gas, and that of the waste gases assuming that the theoretical amount of secondary air was supplied, were given. On this basis, each cubic metre of waste gas entering the recuperator contained 514 k. and retained 216 k. on leaving the recuperator. The author considered that the latter should have been used to generate the steam for the producers instead of the sensible heat of the producer gas; alternately, the recuperators should have been large enough to reduce the final temperature to 250°, which would correspond with 77 k.

The dimensions of the secondary air flues were identical with those of the gas flues. The secondary air entered at approximately 80 mm. W.G. Hence only one-fourth of the theoretical amount of air could enter the furnace. Analyses showed the waste gases to contain 3 per cent. CO. According to the usual empirical calculation this was equal to a 12 per cent. heat loss. Probably the conditions were worse, but, owing to leakage, some secondary air was short-circuited.   H. W. H.

273. An Annealing Furnace.   E. A. HAILWOOD, Morley, near Leeds (Brit. Pat., No. **193967**, December 2nd, 1921).—An annealing furnace for glassware, etc., has an inclined floor or rails, as shown in Fig. 127, and is provided with a controlling device to allow any number of pans to pass at desired intervals. In the form shown, the controller comprises a roller, C, with one or more arms, C^1, to retain the pans, T, in the furnace, and a spring or lever-operated

catch, C^2. The opening of one door of the furnace may be arranged
to open or close the other door and also to operate the controller,
C. The pans, T, are fed into the furnace by a lift, B, operating
in a shaft, S, and move by gravity into the lehr or are pushed by
a bar or chain. As shown in Fig. 127, the rails, F, may have an
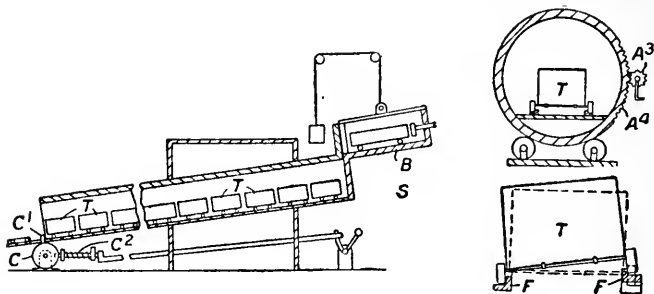
FIG. 127.

undulating form to cause the pans to incline to one side or the
other, or the base of the pan may be slung in such a manner as to
cause the glassware carried to roll so that it may be heated through-
out. One end of the pan may be packed up to keep it level while
running down the incline; or the whole lehr may be arranged
to roll automatically or by hand through part of a circle by the
pinion, A^3, and rack, A^4. The pans may run on rollers. A
double-deck cage may be used for charging.   H. G. C.

274. Protection of Furnaces from Spilt Glass. T. TEISEN,
Birmingham (Brit. Pat., No. **194819**, December 22nd, 1921).—
In a crucible furnace for melting glass, metals, etc., of the kind
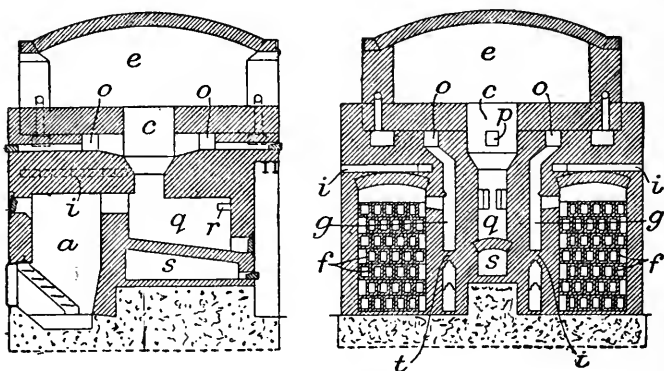
FIG. 128.

in which the heating-means, including recuperators, f, or regener-
ators, are arranged below the crucible chamber, e, and in which
the heating-gases are delivered to the crucible chamber through a
vertical port, c, in the floor, leakage of spilt glass, etc., into the

recuperators is prevented by a system of cooling-passages comprising horizontal channels, i, and vertical chambers, g, the latter of which serve as connections between the recuperators and the delivery ports, p. The chambers, g, may be divided more or less horizontally by a wall, t, having a number of parallel partitions depending therefrom. Beneath the port, c, is a waste pocket, q, and in the construction shown in which the producers, a, are built into the furnace base, a port, r, leading direct to a recuperator is provided so that any accumulation of metal in the pocket will be kept in a molten state. When gas is supplied from an outside source an air port is fitted in the gas supply channel so that combustion is initiated in the waste pocket, q. Beneath the pocket is a cooling-chamber, s. The chambers, g, communicate with the ports, p, through a circular flue, o, or a pair of quadrantal flues, and from the ports cleaning passages extend to the outside of the furnace. The outlets from the cooling-channels, i, are preferably at a higher level than the inlets. The invention may be applied to furnaces having a firebox beneath the port, c.   H. G. C.

275. The Principles of Transference of Heat. G. J. GREEN-FIELD (*J. Soc. Chem. Ind.*, 1923, **42**, 390, 417).—The laws governing the transference of heat by convection, conduction, and radiation were enunciated and their bearing on practical problems was considered. It was pointed out that when a liquid or gas was in contact with a solid surface it behaved as though there were a stationary film or skin of the fluid adhering to the solid, even although the body of the fluid were in motion. Such films were very bad conductors. When heat flowed from a body of hot air to a body of cold air on the other side of a wall, the passage was opposed by three resistances in series, namely : (1) the air film on the hot side ; (2) the solid wall ; (3) the air film on the cold side, and the air films often offered as much or even more resistance than the wall itself. Each portion of the path could be treated separately and thus if k were the coefficient of heat transfer of one film, A the area of film, dT its temperature drop and L its thickness, the rate of flow of heat through this film would be given by $\dfrac{k\text{A}d\text{T.}}{\text{L}}$ Since film thicknesses were, in general, unknown it was better to replace $\dfrac{k}{\text{L}}$ by h, termed the " film coefficient." When heat passed from a solid to a gas at rest the film coefficient usually lay between 1·0 and 2·0. When the gas was in motion, a higher value was obtained and Carrier found for Buffalo air heaters $h = \dfrac{22 \cdot 3v}{1 \cdot 42 + v}$, where v=lb. of air passing per square foot of free area (measured at the point where the free cross sectional area between the pipes was the least) per second. The formula for the film coefficient in the case of the passage of heat to pipes from liquid flowing through them was more complex but had been worked out by McAdams and Frost.   A. C.

276. Heat Economy in the Glass Industry.   (*Sprechsaal*, 1923, **56**, 44, 70, 82, 123, 134, 146, 165, 177).—A series of reports on the investigation of furnace efficiency in various factories by members of the staff of the Technical Heat Advisory Bureau (Wärmetechnischen Beratungsstelle) of the German Glass Industry at Frankfort.   Below are extracts of points of interest :

Case 1.   A hollow ware factory with a twelve-pot furnace, five lehrs and three Siemens producers with natural draught.   Union briquettes were employed as fuel, and these were found to weather badly in the open with loss of calorific value, so needing covered storage room.   By providing forced draught for the furnaces, important economies ensued, the coal consumption sinking from 8 to 5 tons, allowing the factory to be run with two producers. The moist ash considerably opposed the passage of the blast, which was therefore driven through small slits on the grate, whilst to prevent clinkering steam was added to the blast air.   A fuel-bed of depth 1100 mm. was found to be insufficient, and by increasing it to 1300—1500 mm. better results were obtained.   A further fault found was that the layer of ash was too shallow, allowing hot fuel to come in contact with the grate bars, to their detriment, and resulting in excessive clinkering, whereby an ash containing 40 per cent. of combustible (about 6 per cent. of the total fuel) was obtained.   The thicker ash-bed also allowed of a better distribution of the blast amongst the fuel.   Clinker was cleaned out three times each twenty-four hours by means of heavy bars and hammers.   For this process was substituted an hourly raking with thinner rods, thereby preventing hollows in the fuel-bed with a consequent burning of the gas.   Through adjustments of the valve between the collecting flue and the reversal gear, alterations which were rendered necessary by the occasional changes in the amount of gas needed in the furnace, the pressure in the collecting flue was found to vary from 1 to 13 mm. water gauge.   A remedy for this trouble lay in adjusting the blast pressure on the producers to give more nearly the gas production desired at any particular moment, and for the purpose it was necessary to have the air and steam controls and the temperature and pressure recorders near to the producer platform.

Case 3.   A bottle tank heated by a producer of 2·6 m. diameter with a rotating bottom, and two Siemens step-grate producers. The former was fired with Westerwälder lignite, which, since it had a strong tendency to clinkering, was mixed with about one-eighth of Rhenish lignite and Union briquettes.   The gas obtained varied in composition during working over the range : CO_2, 9·4— 11·5 per cent.; CO, 24·7—22·2 per cent.; H_2, 16·5—21·4 per cent. The irregularity was found to be largely due to the method of charging which was done by seven fillings at uneven intervals.   The poor quality of the gas was caused by too great an addition of steam in the blast for the particular fuel used.   A large moisture content damped the zone of reduction, and the difficulty was further enhanced by the hygroscopic nature of the ash.   The remedy lay in adjusting with care the coal : air : steam ratio, and for this

purpose it was necessary to watch the blast saturation temperature by a thermometer placed at a point where the air–steam mixture was complete. By adjusting the blast temperature at first to about 65° it could be regulated by observation until the best results were obtained. In this case also, the waste gases from the furnace were found to have a CO_2 content of only 4·4 per cent. in the gas chamber instead of ·15—18 per cent., an error which proved to be due to a dilution of the original producer gas as it passed through the gas regenerator, the latter possessing leaky walls.

Case 5. A bottle tank with regenerative firing was found to give lower temperatures in the gas regenerators during the passage of the waste gases than during that of the producer gas. Compositions of the gas at the producer and in the port flues gave the following figures :

Percentage composition	CO.	CH_4.	CO_2.	O_2.	H_2.	N_2.
In collecting flue	23·2	3·4	7·8	0·2	7·6	57·2
In port flue	5·4	1·6	14·9	0·4	0·7	76·9

It was obvious in this case that three-fourths of the gas was burning in the regenerators, through the walls of which, due to their thinness and to the negative pressure within large volumes of air were being drawn. A. C.

VIII.—Chemical Analysis.

277. A Rapid Means for the Determination of the Quartz Content of Felspar. M. C. BOOZE and A. A. KLEIN (*J. Amer. Cer. Soc.*, 1923, **6**, 698).—The method depended on the difference in optical properties between felspar glass and quartz. The optical constants of crystalline alkali felspars and quartz might be so much alike that a quantitative microscopic separation would be difficult. This difficulty was overcome by fusing the felspar rapidly at a temperature which was too low to dissolve or fuse an appreciable amount of quartz. Cone 11 was found to be the minimum temperature at which complete fusion in a heat treatment of approximately two hours could be accomplished. A heat treatment corresponding with cone 12, down in one and a half hours, with a fifteen minutes' soaking, was recommended as being the least likely to give erroneous results. The alundum crucible used should not be larger than $1—1\frac{1}{4}$ inches in diameter and the charge should not be more than 20 gm.

Two felspars of the following compositions were tested :

	Al_2O_3.	Fe_2O_3.	SiO_2.	TiO_2.	CaO.
New Hampshire	17·33	Trace	66·69	Trace	Trace
Maine	15·23	0·33	73·50	0·03	0·37

	MgO.	Loss on Ignition.	Na_2O.	K_2O.	Total.
New Hampshire	None	0·21	2·98	12·01	99·22
Maine	None	0·53	4·45	4·75	99·19

The former indicated a 30 per cent. content of quartz, the latter 10 per cent.

For the test, the fused product was pulverised and the powder passing through No. 10 and retained on No. 21 standard silk cloth was used. A slide was prepared by immersing a small amount of the grain in a liquid or resin of the proper index of refraction, for example, clove oil, ethylene bromide, or Canada balsam. The slide was viewed through a polarising microscope, first in ordinary light when the total amount of material in the field of vision was seen, then in polarised light when the amount of transparent material (quartz) was noted. Permanent slides, if required, were prepared by mounting the grains in a medium, such as Canada balsam, which became solid on standing.

To estimate the amount of quartz present, standard mixtures of a pure felspar and quartz were treated and permanent slides prepared.

The method required no knowledge of polarised light or of petrographic methods. The determination could be carried through in two hours and a difference of 5 per cent. in the quartz content could readily be detected.

The paper was illustrated by photomicrographs.   E. M. F.

278. The Analysis of High Alumina Products. C. A. UNDERWOOD (*Bull. Amer. Soc. Cer.*, 1923, **2**, 6).—Ordinary clays could be thoroughly decomposed by fusion with sodium carbonate. For refractory products such as diaspore, bauxite, spinel, etc., and the various products made from these materials with 60 to 85 per cent. alumina content it was necessary to use sodium or potassium pyrosulphate. A detailed description of the process of analysis was given.

Loss on Ignition.—One gram of the sample, dried at 105°, was heated for thirty minutes at not less than 1,000°.

Solution of the Sample.—The sample on which the ignition loss had been determined was pulverised in an agate mortar. An amount corresponding with 0·5 gm. of the original sample was fused with 10 to 15 gm. of fused potassium pyrosulphate in a platinum crucible. The fusion required about three hours, only flocculent silica remaining undissolved. The fusion when cold was dissolved in 150 c.c. of hot dilute hydrochloric acid (1 : 1). Heat was applied until the solution was clear, silica only remaining undissolved.

Silica.—The solution was transferred to an evaporating dish and evaporated nearly to dryness on a water-bath. Dehydration was completed by heating over a hot plate. Fifty c.c. of dilute hydrochloric acid and 150 c.c. of hot water were added and heat was applied until all except the silica was in solution. The silica was filtered off, washed six times with cold water and six times with hot water, ignited, and weighed in a platinum crucible. The impure silica was moistened with a few drops of water, two drops of concentrated sulphuric acid, and 10 to 15 c.c. of hydrofluoric acid were added and the solution evaporated until the sulphuric

acid had been expelled. The residue was ignited and weighed. The difference between the two weights represented the true silica.

Alumina, Iron Oxide, and Titania.—The residue from the hydrofluoric acid evaporation was fused with 1—2 gm. of potassium pyrosulphate and dissolved in the filtrate obtained from the silica separation. The solution was made up to 500 c.c. and 200 c.c. were pipetted out. The platinum dissolved in the process of fusion was removed by precipitating with hydrogen sulphide and filtering. The filtrate was boiled to expel hydrogen sulphide. The iron was oxidised by adding bromine water, the excess of which was boiled off. The solution was diluted to 450 c.c. The alumina, iron, and titanium were precipitated by ammonia, using rosalic acid as indicator. The precipitate was allowed to settle and filtered through a strong filter, the beaker rinsed with hot dilute ammonium nitrate solution and the precipitate then washed five times. The precipitate was redissolved into the original beaker with hot, dilute hydrochloric acid (1—1), the solution diluted to 450 c.c. and the precipitate obtained as before. The new precipitate was washed on the filter five times with ammonium nitrate solution. The large volume of solution was recommended in order to avoid adsorption of fixed alkalies by the alumina precipitate. The precipitate was ignited, blasted for twenty minutes, cooled in a desiccator and weighed with the cover on.

Iron Oxide.—The combined oxides of aluminium, iron, and titanium were fused with 10 gm. of fused potassium pyrosulphate. The fusion was dissolved in 75 c.c. of water and 10 c.c. of concentrated sulphuric acid. The platinum was removed by passing hydrogen sulphide and the solution filtered into a 500 c.c. Erlenmeyer flask. Hydrogen sulphide was again passed until the solution became cloudy owing to the presence of free sulphur. Complete reduction was determined by testing a drop of the solution with potassium sulphocyanide. The flask was supplied with a Bunsen valve and boiled gently until the solution became clear and finally all traces of hydrogen sulphide were expelled. The iron was titrated with $N/25$-potassium permanganate. The end-point was reached when a pink flash was obtained throughout the whole solution.

Titania.—After the titration of iron, titania was estimated colorimetrically in the solution by adding hydrogen peroxide and comparing the colour with that obtained by treating a standard solution in the same way.

Alumina.—By deducting the iron and titania from the total alumina precipitate $(Al_2O_3+Fe_2O_3+TiO_2)$, the percentage of alumina was found.

Calcium Oxide.—The calcium was precipitated as oxalate and after reprecipitating and filtering was treated with 150 c.c. of water and 6 c.c. of concentrated sulphuric acid, heated at about 70°, and titrated with $N/25$-potassium permanganate.

Magnesia.—The magnesia was determined as pyrophosphate. The precipitation of magnesium ammonium phosphate was facilitated by the addition of 50 c.c. of alcohol.

Potash and Soda.—The alkalies were determined by the Lawrence

Smith method, the potassium being separated as potassium platinichloride.

Summation of Results.—Analyses which totalled 102 to 103 per cent. were usually in error only on the determination of alumina. It was important to wash the alumina precipitate thoroughly, as it was capable of adsorbing large amounts of fixed alkalies. The use of impure ammonia and the failure to remove the platinum taken up during fusion added still more to this constituent. In the course of many analyses on products running from 60 to 85 per cent. Al_2O_3, the summation of the constituents had been between 100 and 100·5 per cent. It was considered that where speed was an important consideration, the allowable limit might be extended to 101 per cent.

Directions for the preparation of the necessary solutions were included.   E. M. F.

279. The Rapid Technical Determination of Ferric Oxide and Alumina in Clays and their Burnt Products.   F. LUCCHESI (*Giorn. Chim. Ind. Appl.*, 1923, **5**, 12; from *J. Soc. Chem. Ind.*, 1923, **42**, 225A).—To determine the ferric oxide and alumina content of clays, hydraulic limes, cements, etc., the silica and manganese were first removed and the iron and aluminium then precipitated as hydroxides in the usual way. After washing free from chlorides, the filter-paper and precipitate were boiled with a known volume, in excess, of $N/2$-sulphuric acid to dissolve the hydroxides.

To the cooled liquid was added 2 drops of 0·02 per cent. methyl orange and it was then titrated with $N/2$-caustic soda until the red tint just disappeared. The difference in volume between the amounts of acid and alkali used gave the acid equivalent of the two hydroxides. Finally, the solution was mixed with 1 c.c. of concentrated sulphuric acid reduced by hydrogen sulphide and titrated with $N/10$-permanganate. This allowed of the estimation of the iron oxide, and, by difference, of the alumina. In four examples given the alumina was in each case within 0·2 per cent. of the value obtained by the ordinary method, whilst the iron oxide values differed by 0·05 to 0·08 per cent. from the ordinary results.   A. C.

280. Note on the Determination of Volatile Matter in Fuels. P. WEDGWOOD and J. HODSMAN (*J. Soc. Chem. Ind.*, 1922, **41**, 372T).—As a substitute for platinum crucibles in the American method of determining volatile matter in fuels, the authors found crucibles of Monel metal and of mild steel, treated with aluminium powder, to be quite satisfactory. Such crucibles were turned out of the solid and were similar in dimensions to the ordinary platinum crucibles, but had a $\frac{1}{16}$in. hole pierced in the lid. They were first embedded in aluminium powder enclosed· in an iron tube and heated in a muffle as in the commercial process for "calorising." After this treatment, a preliminary heating of the crucible in a Méker burner for seven minutes at 950° indicated that the effect

of oxidation on the crucible itself during the determination of volatile matter would lower the result by 0·5 per cent. as compared with determinations in platinum. A. C.

281. The Separation of Ferric Oxide and Alumina from Magnesia by the Nitrate Method. A. CHARRIOU (*Compt. rend.*, 1922, **175**, 693).—The separation of ferric oxide and alumina from magnesia by means of Sainte-Claire Deville's nitrate method was incomplete, due to the occlusion of magnesia in the precipitate. The author investigated ways of decreasing the amount occluded.

After heating, the oxides were taken up in 50 c.c. of boiling 4 per cent. ammonium nitrate solution, the solution kept hot for an hour, then washed with boiling water. The heat treatment of the oxides was varied, from the stage of decomposition of ferric nitrate, approximately at a temperature of 150°, to the beginning of the decomposition of the magnesium basic nitrate, about 350°. The occlusion was found to be least when the heating was discontinued at the temperature 150°. The amount of magnesia held by alumina was less than that held by ferric oxide.

The sesquioxides having been formed by heating the nitrates not higher than 150°, they were treated separately with 50 c.c. boiling ammonium nitrate solution (10 per cent.). The mass was kept hot for one hour, then the supernatant liquid was decanted off, and the solids were washed with boiling water.

When the mass was taken up in one volume (50 c.c.) of ammonium nitrate, very little magnesia was retained by the iron oxide, and only a trace by the alumina. Three treatments with hot ammonium nitrate prevented any contamination of ferric oxide, or alumina taken separately, or in mixtures.

The sesquioxides were obtained again by precipitation with ammonia of concentration 11 molecules per litre, using 2 c.c. in presence of ammonium nitrate. The precipitate was dried at a temperature not exceeding 150°, then taken up, and washed with boiling water. The occlusion of magnesia was only slight in the ferric oxide and alumina. V. D.

282. Available Hydrogen in Coal, and a Direct Method for its Estimation. J. D. DAVIS (*Ind. Eng. Chem.*, 1923, **15**, 594).—Six American coals were analysed by the volumetric method devised, and the values obtained for the available hydrogen were found to agree quite well with those obtained from the gravimetric analysis. The available hydrogen was calculated from the analysis on the assumption that all the hydrogen content of the coal in excess of that required to saturate the combined oxygen was available.

The method, the essentially new features of which consisted of a combustion pipette and a burette, gave the volume of oxygen that had to be supplied in order to saturate the hydrogen of the coal, taken as available or combustible.

A 100 c.c. sample of the combustion products was analysed by usual standard methods for CO_2 and residual oxygen. The

total carbon was calculated from the CO_2. The sulphur appeared in the products as SO_3.

This volumetric method did not give as strictly accurate results as the usual gravimetric method, especially with high oxygen coals, but it certainly was rapid.

For details of the apparatus the original paper should be consulted.   V. D.

IX.—Machinery for the Working of Glass.

283. A Bottle Blowing Machine. R. LA FRANCE, Toledo, Ohio, U.S.A., Assignor to the OWENS BOTTLE CO., Toledo, Ohio, U.S.A. (Brit. Pat., No. **192347**, March 16th, 1922. Convention date, January 30th. Not yet accepted).—A glassware-forming
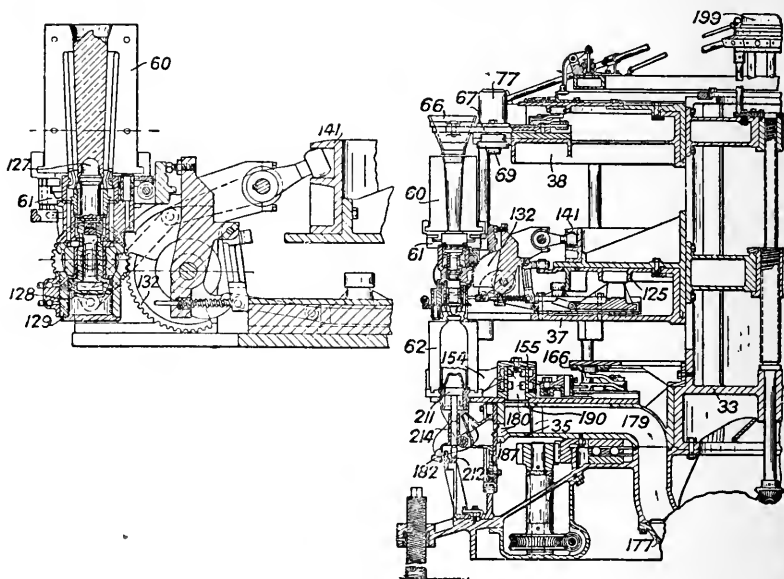
FIG. 129.

machine of the turnover type in which a continuously rotatable carriage carries a series of parison moulds and finishing moulds has devices individual to each parison mould for closing the charging opening in the top thereof, means for inverting the parison moulds before they are opened to release the parisons, and means for reinverting the parison moulds independently of the ring moulds.

The carriage supporting the moulds consists of a lower section or spider, 35, an intermediate section, 37, and an upper section, 38, all adjustable vertically in respect to one another and rotatable

about a central column, 33. A number of mould units are arranged symmetrically around the carriage and each comprises a parison mould, 60, a ring mould, 61, a finishing mould, 62, and a plate, 67, which slides radially and supports a funnel-shaped guide, 66. As each mould unit is brought to the charging position, a charge of molten glass, preferably supplied by an automatic feeder, is dropped into the funnel and is guided by it into the open end of the parison mould, 60. Immediately after the mould receives its charge, the plate, 67, is moved radially outward and brings a closing-head, 69, over the mould. Compressed air from a distributor, 199, is admitted to a cylinder, 77, which closes the head, 69, on to the mould. The closing of the head may open a valve to admit air above the glass to pack it down into the mould. Alternatively, the packing of the glass may be accomplished by connecting the ring mould with a vacuum tank. Air is also applied to a cylinder, 129 (Fig. 129), to project the plunger, 127, into the ring mould, the plunger being lowered, after the supply of air to the cylinder, 129, is cut off, by a constant pressure of air maintained on a narrow annular portion of the upper part of the piston, 128. As soon as the plunger is lowered, air is admitted around the plunger to blow the glass to fill the parison mould, the blow head, 69, being removed after the parison is blown.

The parison mould, ring mould, and associated parts are mounted on a horizontal axis, and after the parison is blown they are swung downwards from the position shown in Fig. 129 by means of segmental gears, 132, operated by a cam, 125. A cam, 141, then opens the parison mould, which is swung into the upward position again, thus leaving the parison suspended from the ring mould. The sections of the finishing mould, 62, which are pivoted on a sleeve, 155, are closed about the parison by a cam, 166, the mould bottom, 211, being raised into position by a cam, 212. The mould bottom is carried by a pivoted bracket, 214, and after the bottle is blown and the mould again opened, the bracket is tilted outwards to discharge the bottle.

Air for cooling the moulds, supplied from a hollow casting, 177, at the base of the machine, is conducted through channels, 179, and ports, 180, to nozzles, 182, by which the air blasts are directed against the mould bottoms, 211. The channels, 179, also communicate with the hollow sleeves, 155, which have ports opening into the hollow arms, 154, of the finishing moulds, whence the air blast passes through slots against the moulds. Other pipes direct air against the parison moulds. A damper, 187, controls the air supply of the ports, 180, and a sliding plate, 190, controls the supply to the sleeve, 155.   H. G. C.

284. Improvements in Glass Bottle Blowing Machines. O. Y. IMRAY, London, and the OBEAR-NESTER GLASS Co., St. Louis, Missouri, U.S.A. (Brit. Pat., No. **193080**, September 12th, 1921).— Relates to machines for blowing glass bottles of the kind comprising two rotatable tables carrying the blank and finishing moulds respectively and provided with inverting and transferring mechanism

between the moulds and with a punty-operated element actuated
by the lowering of a gather into a blank mould to control pneumatic
means for severing and packing the gather, opening the mould,
operating the transferring and inverting mechanism to convey the
blank within the finishing mould. According to the invention,
the shearing mechanism is combined with a blow head for packing
the gather, the transfer mechanism is adapted to grip the necks
of the inverted bottles in the blank moulds and to deposit them
in an upright position in the finishing moulds, and the blank moulds
are covered by a vertically movable but non-rotary top disc carried
by the piston rod of a pneumatic cylinder upon which the mould
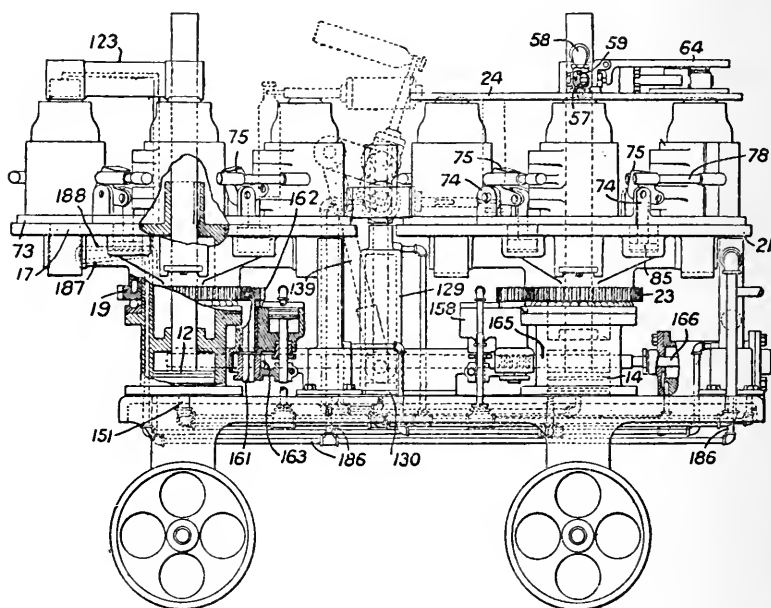
Fig. 130.

table rotates, the disc being cut away at one sector to enable the
bottles to be removed from the blank moulds.

Figs. 130, 131 and 132 illustrate a five-station machine, the opera-
tions at the various stations being as follows, namely, for the
blank table, at station 1, charging, shearing, packing, and removal
of neck pin; station 2, initial blowing; station 3, transfer to finish-
ing mould; stations 4 and 5, idle; for the finishing table, at station
1, blank received and mould closed; station 2, idle, allowing glass
to cool; station 3, bottle blown; station 4, idle; station 5, finished
bottle removed.

A combined shearing-plate and blow head, 38, is mounted upon
a stud, 35, on the top disc, 24, which is provided with an opening,
28, at the first position for the introduction of the charge. As the
latter is introduced, the punty depresses a lever, 64, opening a

value, 59, which admits compressed air from pipes 182, 154, pipe 72, and pipe 57, to a pipe, 58, and cylinder, 46, to rotate the shearing-plate, 38, and sever the charge.   As the movement of the shearing-plate finishes, compressed air is admitted through pipes 66, 67, 69, to a port, 36, in the stud, 35, and passes through a passage, 43, and cluster of air vents, 45, in the shearing-plate to the mould, thus effecting the packing of the gather about the neck pin at the bottom of the mould.

A portion of the compressed air passes from the pipe 67 to the pipes 68, 189, thus depressing the piston 172, throwing the pipe 154 open to exhaust and admitting compressed air from the pipe 182 to the pipe 170.   While the piston 172 is in its upper position, pistons 12, 14 (Fig. 130), are held in their lower positions by compressed air admitted above them, thus depressing the blow head, 123, and top plate, 24, respectively into contact with the moulds beneath.   As soon as the piston 172 rises, the spaces above the pistons 12, 14 are thrown open to exhaust and air is admitted from the pipe, 170, beneath these pistons, which rise to their upper positions freeing the moulds from engagement with the blow

Fig. 131

head, 123, and top plate, 24.   The upward movement of the piston 172 is effected by compressed air admitted from the pipes 188, 187, 186, after the rotation of the tables 17, 21 is completed.   The upper end of the piston 175 engages with holes, 174, in the rotary table, 21, when in the upper position so as to lock it and prevent rotation.

At the moment when the piston 14 rises, compressed air is admitted from the space below the piston to the space above a piston, 100, Fig. 131, withdrawing the neck pin as shown.

The pipes 154, 170 are connected to the upper and lower ends of two vertical cylinders, 158, adapted to raise and lower gear wheels, 163, slidably mounted on shafts, 161, carrying pinions, 162, in engagement with ring gears, 19, 23, secured to the rotary mould tables.   When in their upper positions, the gears, 163, engage with a rack, 165, operated by a piston rod, 166.   When compressed air is admitted to the pipe 170, the gears, 163, first engage with the
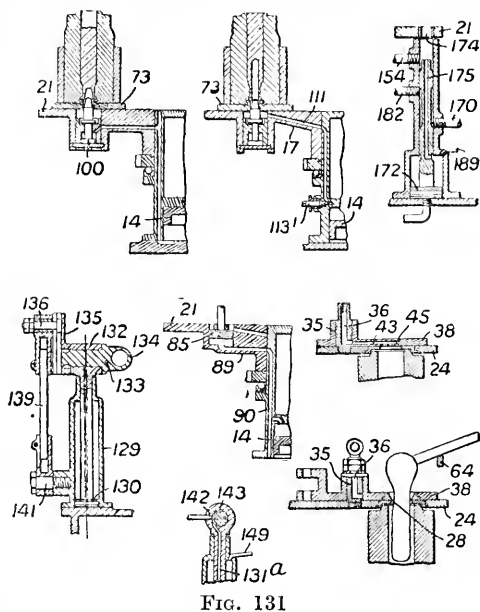
rack and the piston rod 166 is then forced outwards, thus rotating
the mould tables through 73° to bring the moulds to the next
stations. When the piston 172 rises, the gears, 163, drop out of
engagement with the rack, and the piston rod 166 moves inwards
ready for the next operative stroke.

Initial blowing of the blank is effected at station 2, by the admission of compressed air through a port, 111, from the space above
the piston 14. The extent of blowing is regulated by a throttle
valve, 113[1].
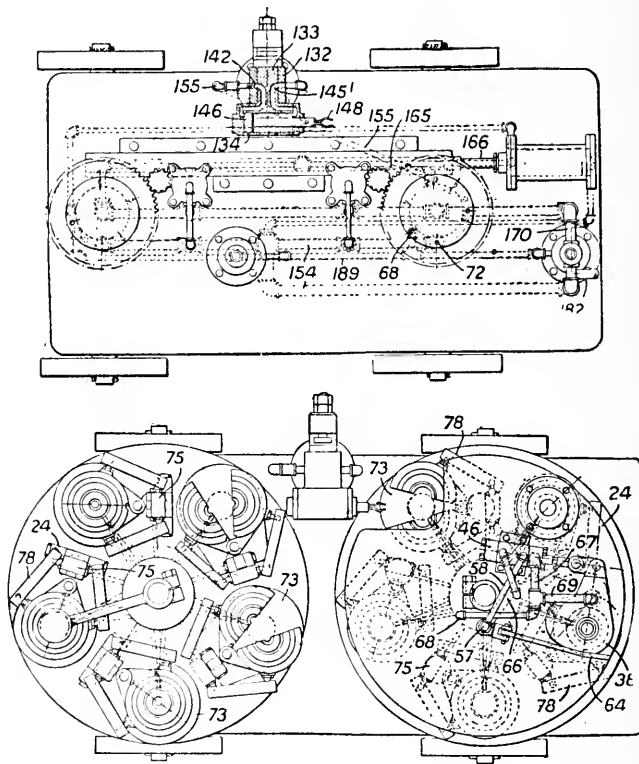
Fig. 132.

The mould plates, 73 (Fig. 130), carry projections, 74, on which
are mounted bell crank levers, 75, connected by links, 78, to the
half sections of the moulds. Cylinders are formed in the mould
plates, 21, beneath each bell crank lever containing pistons, 85,
which are raised just before a mould reaches the third station by
the engagement of the ports, 89, 90, as shown.

Simultaneously with the opening of the mould at the third
station, air is admitted from the port, 90 (Fig. 131), through a pipe,
155 (Fig. 132), to a port, 142, and cylinder, 134, driving a piston,
146, outwards so that grippers, 148, carried by the piston rod engage

the neck of the bottle in the open mould. The cylinder, 134, is mounted on a stud, 133, rotatably mounted in a bearing, 132, which can be raised and lowered by a piston, 130, working in a cylinder, 129. A crank arm, 135, is carried by the stud, 133, the crank pin, 136, being adjustably coupled to a rod, 139, pivoted at 141 to the cylinder, 129. Immediately after the grippers, 148, have engaged a bottle, compressed air from the port, 142, passing through passages, 143, 131[a], to the space below the piston, 130, forces the latter upwards and operates the transfer device as indicated in dotted lines in Fig. 130, to deposit the bottle in an upright position in an open finishing mould. As the movement is completed, the port, 145[1], comes into engagement with the port, 142, and the gripper is retracted from the bottle. The transfer mechanism is returned to its original position by compressed air passing from the lower side of the piston, 12, through a pipe, 151, and pipe, 149, to the space above the piston, 130.

The mechanism for opening and closing the finishing moulds and for raising and lowering the blow head, 123, are of similar construction to those employed for operating the blank moulds. Specification 193365 is referred to.   H. G. C.

285. Improvements in Blowing Machines. R. HADDAN, London, and the CORNING GLASS WORKS, Corning, New York, U.S.A. (Brit. Pat., No. **194889**, February 7th, 1922).—Relates to the blowing machine described in Specification 21611/12 and
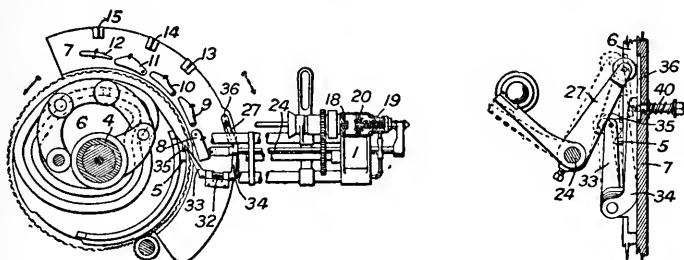
FIG. 133.

consists in providing means for actuating the air pump of the machine in such a manner as to give the initial puff to the parison either while the frame is still in the marvering position or before any substantial movement has taken place. The machine comprises a blow-pipe frame, 1 (Fig. 133), which oscillates about a bearing, 4, and carries an air pump, 18, the piston, 20, of which is pressed forwards by a spring, 19. As the frame swings from the horizontal position shown, in which the parison is marvered, to the vertical position, in which the parison is blown, a number of cams, 8—12, and projections, 13—15, on a stationary plate, 7, reciprocate and rotate, respectively, a rod, 24, so that it withdraws the piston, 20, and releases it several times, thus imparting to the parison a succession of air puffs to cause it to expand. In the piston shown, an arm, 27, secured to the rod, 24, rests on a plate,

14—2

36, that lies in a recess in the plate, 7. This plate is kept in the recess by a spring, 40, but can be raised above the surface of the plate, 7, by means of an arm, 34, of rock shaft, 32, another arm, 33, of the shaft being provided with a roller, 35, that rests on a cam disc, 6. When the machine is operated, the motion of the disc, 6, carries a stud, 5, beneath the roller, 35, thus raising the arm, 34, and therefore the arm, 27, and the rod, 24. This momentary movement of the rod, 24, releases the piston, 20, and an initial puff is imparted to the parison while it is still in the marvering position.   H. G. C.

286. An Automatic Feeding Device. E. O. HILLER, Hartford, Conn., U.S.A., Assignor to BRITISH HARTFORD-FAIRMONT SYNDICATE, LTD., London (Brit. Pat., No. **195927**, October 25th, 1922. Convention date, April 6th. Not yet accepted).—An automatic feeder having a number of elements which co-operate to deliver the charges
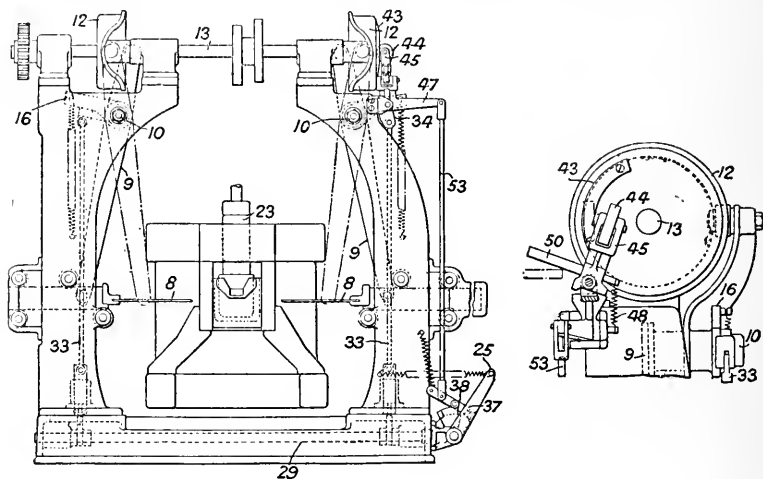
FIG. 134.

of molten glass has means for independently rendering one of the elements inoperative, and means for returning the element to operation in proper relation to the operation of the other elements. The invention is shown in Fig. 134 applied to a paddle feeder and consists of a device for stopping the operation of the shear blades, 8, and for starting them again in proper relation to the strokes of the paddle, 23. The blades, 8, are reciprocated horizontally by levers, 9, pivoted at 10 and operated by springs, 34, and by cams, 12, on a shaft, 13. A handle, 25, is connected by segmental gears with a shaft, 29, which raises or lowers slides, 33, the upper ends of these slides being connected to arms, 34, pivoted on the studs, 10. By turning the handles, the slides can be raised to lift the arm, 16, of the shear levers, 9, and thus hold the shears in the inoperative position. A latch, 38, engages a lug, 37, and prevents

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the return of the handle, 25. The latch is connected by a rod, 53, with a bell crank, 47, on which is pivoted the yoke, 45, of a roll. 44. A spring, 48, normally holds the roll, 44, out of the path of a cam, 43, fixed on one of the shear cams, 12. When it is desired to start the shears, a handle, 50, is turned to bring the roll, 44, into the path of the cam, 43. The cam thus raises the latch, 38, and allows the shears to come into operation at a particular point in the rotation of the shaft, 13, and, therefore, in proper relation to the rest of the mechanism.   H. G. C.

287. Improvements in Feeding Devices. K. E. PEILER, Hartford, Conn., U.S.A., Assignor to the HARTFORD-EMPIRE Co., Hartford, Connecticut, U.S.A. (Brit. Pat., No. **195376**, March 19th, 1923. Convention date, March 25th, 1922. Not yet accepted).— Relates to an automatic feeding-device and consists in providing means whereby the feeder delivers charges of molten glass of different predetermined weights in regular succession, so that articles of different weights may be made with one feeder. The invention is particularly applicable to the type of feeder in which glass, 10 (Fig. 135), contained is a forehearth, 11, discharges through an outlet, 12, and is cut off into charges by shears, 36, the flow of metal being arrested and the cut end of the glass reheated by a gas flame burning under pressure in a cup, 14, which is moved into and out of the operative position. The variation in the weight of the charge delivered is obtained by varying the time during which the burner 14 is closely adjacent to the outlet, 12.

The arm, 15, carrying the cup, 14, is secured to a vertical rod, 16, which is mounted loosely in a standard, 19, and is reciprocated by a rocking-lever, 20. A pin, 27, fixed to the rod, 16, engages a slot, 26, in the standard, 19, the slot being so shaped as to swing the cup out of the way of the falling charge. The rod, 16, also operates a valve that controls the supply of gas to the burner, 14, and cuts off the main supply when the cup is lowered into an inoperative position but permits a pilot light to be fed by a bye pass. The lever, 20, is rocked by cams on a shaft, 52, and the shear blades, 36, are also operated by a cam on the shaft, 52. The lever, 20, is actuated by a number of cams, the number corresponding to the different sizes of charges that are to be delivered. Each cam comprises two members, 51, 53, the member, 51, being fast and the member, 53, being loose on the shaft, 52. An arm, 47, 48, or 49, forming part of the lever, 20, rests on each cam. The loose member, 53, is formed integral with a bevel gear, 55, which is driven through a small bevel pinion, 56, from another bevel wheel, 57, loose on the shaft, 52. The gears, 57, are rotated in the opposite direction to the shaft, 52, and at an equal speed, so that the two members, 51, 53, of the cams rotate in unison. The small bevels, 56, are mounted on segmental gears, 61, that can be rotated about the shaft, 52, by turning handwheels, 64. Thus by means of these handwheels the two sections, 51, 53, can be moved relatively to one another and the shape of the cam can be altered. The shape of the cam regulates the period during which the cup, 14, is close

to the outlet, 12, and thus regulates the amount of glass which passes through the outlet between successive operations of the
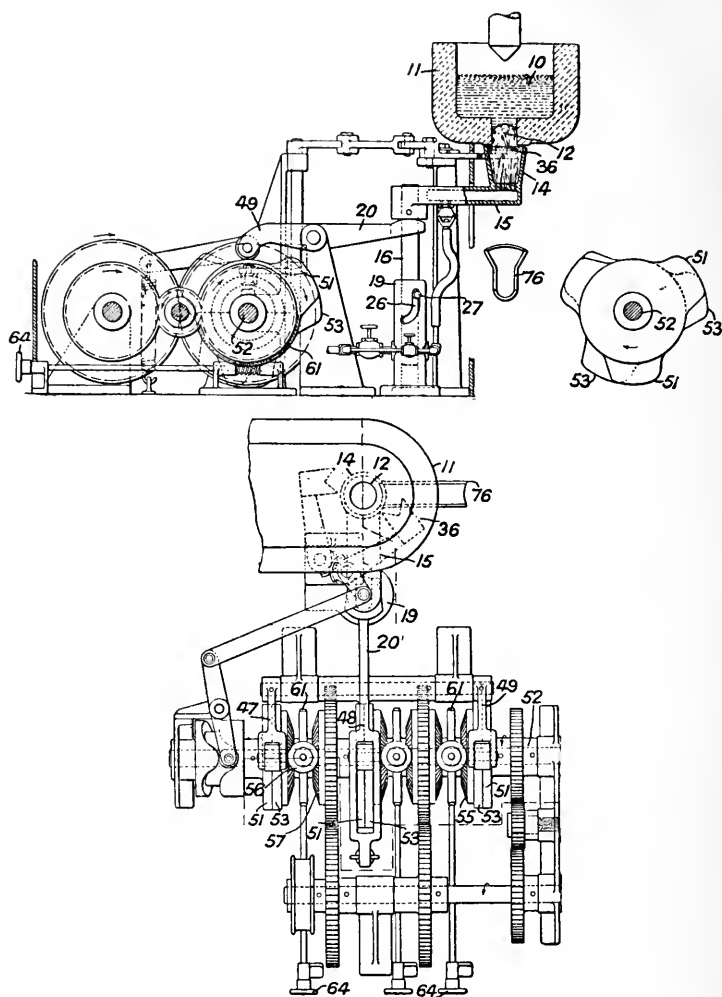
FIG. 135.

shear blades. The space between the top of the cup, 14, and the outlet may be adjusted to regulate the pressure of the gas flame on the stub of glass. The charges may be guided into the moulds by means of a shoot, 76, as described in Specification 104605.

<div align="right">H. G. C.</div>

288. A Device for Delivering Charges of Molten Glass. H. H. PITT, Lesbury, Northumberland (Brit. Pat., No. **195448**, December 29th, 1921).—A feeder for delivering charges of molten

glass to a forming-machine comprises a damper for controlling the flow of hot gases from the furnace, a gate or valve for regulating the flow of metal along a forehearth or spout, and a reciprocating plunger which is cooled internally and is fitted with a suction device for intermittently retarding the flow of metal through an orifice in the forehearth. The metal passes from the furnace, 21, through a channel, 20, to the plunger, 23, the flow of metal being regulated by a gate, 22, and its temperature being controlled by a damper, 24. This damper consists of an iron or steel box through which water is circulated to enable its temperature to be controlled. The adjustable gate, 22, Fig. 136, is formed at its lower end
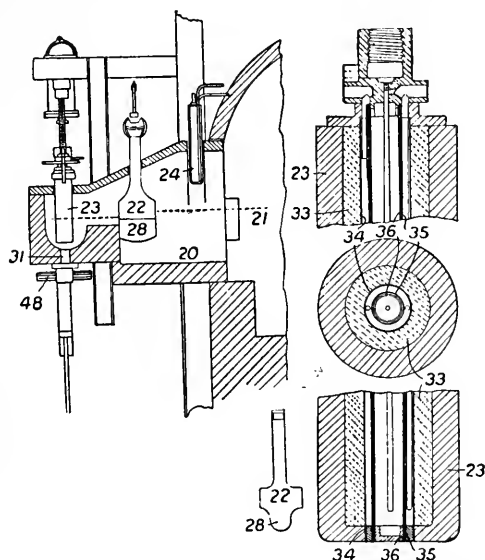
FIG. 136.

with a central depending tongue, 28. Thus, when the gate is raised to the position shown in Fig. 136, the metal flows around the tongue and along the side portions of the spout. It is stated that the retardation of the central and hotter portion of the stream of metal maintains a more uniform temperature throughout the metal. The reciprocating plunger, 23, shown in section in Fig. 136, consists of an outer cylinder of refractory material provided with a non-conducting lining, 33, within which are three concentric steel tubes, 34, 35, 36. The inner tube, 36, forms a chamber for the circulation of cooling water, and also co-operates with the tube, 35, to form a very narrow annular chamber which is connected with a vacuum pump. Suction is applied at the commencement of the upstroke of the plunger and its effect is to retain and lift the metal out of the feed aperture, 31, so that fresh, hotter metal flows beneath it. The narrowness of the annular chamber prevents the entry of metal,

and the cooling of the plunger prevents the metal from sticking to the bottom.   The suction is released near the top of the upstroke so as to free the chilled metal.   The movements of the shears, 48, and of the plunger, and also the application of the suction, are all controlled by valves which are actuated by cams on a common shaft.   Means are provided in connection with the valve operating the shears for giving an additional impetus to the blades immediately they have cut the glass, whereby they are instantly withdrawn and chilling by the shears is avoided.   H. G. C.

289. The Manufacture of Sparking–plugs.   R. HADDAN, London, and the CORNING GLASS WORKS, Corning, New York, U.S.A. (Brit. Pat., No. **196721**, February 7th, 1922).—A sparking-plug is made by electrically heating the central electrode in order to drive off occluded gases and then moulding a core of molten glass around the electrode, an expansion space being afterwards

FIG. 137.

formed around the lower end of the electrode and the tips of the glass core fire polished.

The plug comprises a central electrode, 1, a core, 2, of lower-expansion borosilicate glass, moulded around the electrode and inside of a metallic band, 3, and a shell member, 4, into which the band screws.   The electrode, 1, consists of an upper portion, 5, of small diameter, preferably made of molybdenum or tungsten, and a lower portion, 6, preferably of a nickel-manganese alloy, welded to the portion, 5.

A mould for making the plugs consists of a two-part body, **13**, a base, 12, and blocks, 19, which are secured in recesses in the body, 13, but are separated from the body sections by a layer of insulating material, 20, such as mica.   The blocks, 19, are recessed to receive the metal band, 3, of the plug.   In operation, an electrode, 1, is placed in a vertical bore, 23, in the base of the mould and is clamped in place by a screw.   The ring, 3, is inserted in a recess, 14, in the base and the mould is closed.   Electricity, supplied by leads, 26, 27, secured to the mould parts, is passed through the electrode, the current being sufficient to heat the electrode and to drive off

occluded gases. Molten glass is next delivered to a well, 21, in the body of the mould, and is pressed by a plunger, 28, through passages in the body into the moulding-space, 16.

After the removal of the plug from the mould, the expansion space, 10, in the tip is formed while the glass is still hot.

This may be done by inserting the projecting end of the electrode in the gauze of a gas burner, 29, and moving the plug to work the softened glass away from the electrode. The heating of the tip of the core also fire polishes the glass at that point. The excess glass, X, left by the pressing operation, is removed by breaking and grinding.   H. G. C.

290. A Method of Finishing Glassware. R. Haddan, London, and the Corning Glass Works, Corning, New York, U.S.A. (Brit. Pat., No. **196722**, February 7th, 1922).—A method
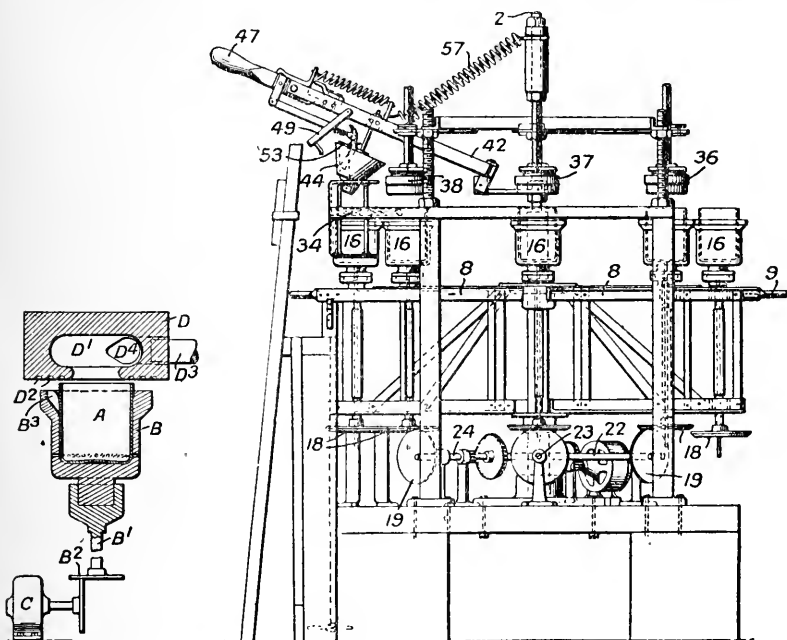
Fig. 138.

of finishing glassware, particularly for flanging and lipping beakers, consists in heating the portion of the article to be finished and rotating the article at such a velocity that the heated portion is forced by centrifugal force to conform to the shape of a former. As shown in Fig. 138, the unfinished beaker, A, consisting of a cylindrical blank, the upper part of which has been cracked off, is inserted in a mould or form, B. This form is mounted on a vertical shaft, B^1, carrying a disc, B^2, that is rotated by friction from a motor, C. The inner surface of the form is flared outwardly at

its upper edge and is provided with a **V**-shaped notch, B^3, for shaping the lip of the beaker. The heating device consists of a shell, D, of refractory material provided with an open circular cavity, D^1. The tip of the burner, D^3, is inserted in an opening, D^4, in the shell tangential to the wall of the cavity. The flame swirls around the cavity and passes downwardly into the article, A. Corrugations, D^2, formed on the underside of the shell, retard the escape of the hot gases over the edge of the article and radiate heat against the edge. The sharp edge of the article is thus melted and fire polished, and the rotation of the form causes the softened edge to turn outwardly and take the shape of the form. The machine, shown in Fig. 138, comprises several forms, 16, carried by a frame, 8, which can be rotated about a standard, 2, by means of handles, 9. Friction wheels, 18, secured to the spindles of the forms, ride over friction wheels, 19, secured to shafts, 22, 23, 24, and are driven by them when the frame is stopped at the different operating stations. Burners, 36, 37, 38, are situated above the stopping-points of the containers. A horizontal rotatable wheel, 34, situated at the station where the flange of the beaker is formed, has a shaped edge which acts as a form to shape the flange when the heated glass is forced outwards by centrifugal force. The lip of the article is formed by a device carried by a pivoted arm, 42, that is held upwards by a spring, 57. The arm, 42, carries a conical shell, 44, which enters the mouth of the article, when the arm, 42, is depressed by a handle, 47, and supports the glass during the formation of the lip. After the shell has entered the article, continued movement of the handle, 47, causes a small arm, 53, pivoted in a recess in a shell, to move outwards and form the lip, another arm, 49, being moved inwards at the same time to support the lip from the outside.   H. G. C.

291. Toughening Glass by Heat Treatment. R. HADDAN, London, and the CORNING GLASS WORKS, Corning, New York,

FIG. 139.

U.S.A. (Brit. Pat., No. **197381**, February 7th, 1922).—A method of heat treatment of glass articles consists in rapidly cooling the article, from a point above the annealing temperature of the glass of which it is composed, by high velocity air jets directed on the article substantially normal to its surface. The method can be carried out by placing the hot article, A, in a nozzle, B, having a suitable holder, C, formed therein, so that the article is positioned between the nozzle, B, and another nozzle, D. The nozzles are directed towards one another and are connected to a supply of compressed air. The nozzles are placed so as to direct the air substantially normal to the surface of the article, A, and this is assisted by placing a perforated distributing cone, F, inside the lower nozzle, B.   H. G. C.
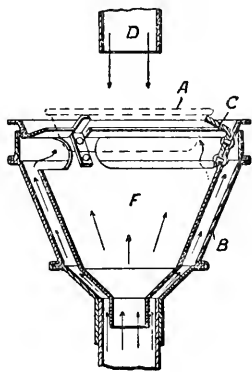
292. A Device for Stirring Optical Glass. Sir C. A. Parsons, Newcastle-on-Tyne (Brit. Pat., No. **191842**, October 22nd, 1921).—
A stirrer for use in the manufacture of optical glass is provided with means for giving it a rapid rotatory motion about its own axis with or without a relatively slow orbital motion. A clay stirrer of the usual cylindrical shape but provided with projections or paddles, *b*, which may be arranged in spiral formation as shown, is attached to a water-cooled iron core, *c*, which is rotated by a driving-shaft, *h*, through bevel wheels, *d*. The wheels are enclosed in a chamber, *e*, through which water is circulated by pipes, *k*, *m*. The clay stirrer shown may be replaced by one of metal which may consist of a helical loop of solid-drawn steel tube. In addition to the rotation about its axis, the stirrer may be given a slow orbital motion by any convenient mechanism.

H. G. C.
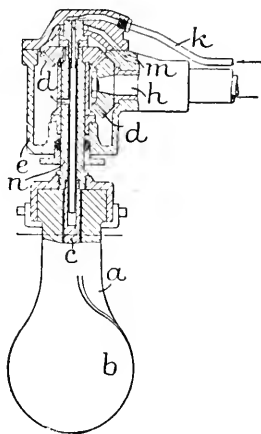
Fig. 140.

293. A Machine for Drawing Sheet Glass. E. C. R. Marks, London, and the Libbey-Owens Sheet Glass Co., Toledo, Ohio, U.S.A. (Brit. Pat., No. **192427**, August 3rd, 1921).—A machine for drawing sheet glass comprises a receptacle from which the molten glass flows in approximately sheet form vertically downwards, a drawing mechanism which grips the sheet on opposite sides and travels downwards, width-maintaining devices which act on the edge of the sheet, and means for severing the drawn sheet and swinging the several sections into a horizontal plane and delivering them into a lehr. The molten metal from which the sheet is drawn is contained in a forehearth 1 (Fig. 141), which is formed with an opening, 2, that tapers to a narrow slot. Temperature-regulating devices, consisting of hollow castings, 3, through which water is circulated, are arranged on each side of the opening, and the distance between these castings may be adjusted to regulate the width of the slot. In place of the slot, an opening, 8, may be arranged at the end of the forehearth through which the metal is allowed to flow in a shallow stream, 9, over the surface of a hollow water-cooled casting, 10. The emerging sheet is gripped by rolls, 12, preferably roughened or corrugated, which are geared together and driven in any suitable manner. A pair of these rolls grips the opposite edges of the sheet and overcomes any tendency to draw in or narrow. The drawing is continued by grippers, carried by endless chains, 18, 18′, which grip the sheet at the edges, contact with the sheet being maintained by spring-pressed rollers, 76, which bear against the inner runs of the chains. The sheet as it emerges from between the chains is acted on by a suitable scoring device, 21, and then passes between idle rollers, 22, 23. Beneath the drawing-apparatus

is a swinging carrier-frame composed of slots, 44, secured to a shaft, 42, and provided with ledges, 44a, for receiving the lower edge of the descending sheet. A counterbalanced lever, 24, pivoted at, 25, projects into the path of the sheet and is thus depressed as the sheet descends. At a particular point, the lever closes contacts 30, 31 in the circuit of the motor, and the motor thus started drives a cam, 41, and rotates the shaft, 42. The frame is first moved backwards a little distance to break the sheet along the scored line, and then swings downwards to deposit the severed section
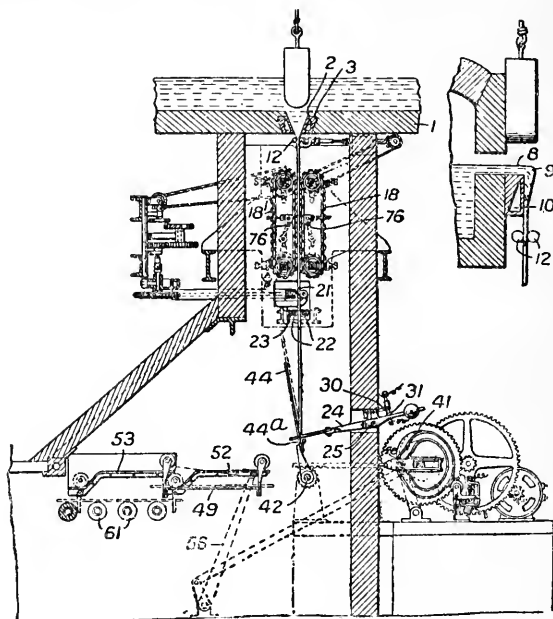
Fig. 141.

on a carriage, 49. This carriage is moved forwards along rails, 52, 53, by a lever, 56, oscillated by the motor, and deposits the section on lehr rollers, 61, which feed it into the lehr. In a modification, the carrier, 44, is made up of tubes which are secured to the shaft, 42. The tubes are provided with openings, each surrounded by a flexible cup, and are connected to a suction pump. The flexible caps make contact with the sheet which is held by suction. The drawing mechanism comprising the endless chains with the grippers for engaging the edges of the sheet may be used in a machine of the type in which the sheet is drawn vertically upwards.   H. G. C.

294. A New Method of Drawing Sheet Glass. A. E. WHITE, London, and the PITTSBURGH PLATE GLASS Co., Pittsburgh, U.S.A. (Brit. Pat., No. **192848**, November 30th, 1921).—A process of drawing glass in flat sheets consists in fixing the position of the

line of generation of the sheet by a guiding-device submerged in the molten glass, interrupting the flow of surface glass to the sides of the sheet by means of refractory devices projecting above the surface of the glass on each side of the sheet, and applying heat to the surface of the glass between the refractory devices and the sheet. As shown in Fig. 142, the melting tank, 1, has a forehearth or drawing-tank, 2, which is arched over with a crown, 4, and a block, 5, L-shaped shielding-members, 6, 7, being arranged in between the crown and the block to protect the sheet, 3, as it is drawn.   A refractory trough or receptacle, 10, provided with a central slot, 11, and side slots, 12, 13, arranged and shaped as shown in Fig. 142, is placed beneath the line of generation of the sheet. The edges, 14, 15, of the receptacle extend above the surface of the glass closely adjacent to the shields, 6, 7. These edges interrupt the flow of surface glass towards the sheet, and the space between
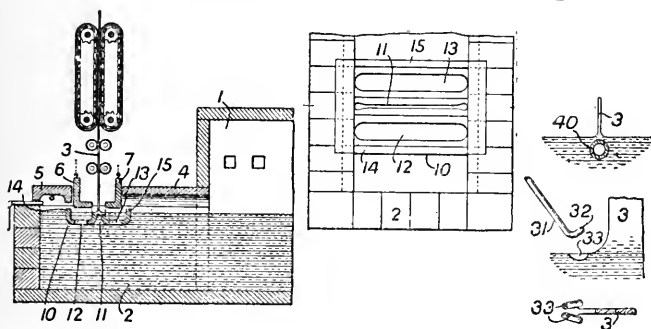
Fig. 142.

the edges and the member, 6, 7, permits the circulation of hot gases over the body of glass lying within the receptacle. The use of the receptacle ensures a free flow of relatively hot glass into the sheet and the slot, 11, tends to fix the line of generation of the sheet. In a modification, the receptacle may be replaced by a slotted bar of refractory material submerged in the glass, other bars serving to prevent the flow of the surface glass into the sheet.   In a further modification, shown in Fig. 142, a water-cooled tube, 40, or a refractory bar having a U-shaped upper edge, is submerged in the glass and tends to fix the line of generation of the sheet.

In order to counteract the tendency of the sheet to draw in at the edges, a rod, 31, curved at its end, 32, is used to form depressions, 33, in the glass on either side of the edges of the sheet. These depressions are made at intervals during the drawing, and the consequent cooling of the glass makes it stiffer near the edges of the sheet.   H. G. C.

295. A New Method of Drawing Sheet Glass Continuously. C. W. AVERY and E. T. BROWN, Detroit, Michigan, U.S.A., Assignors to the FORD MOTOR Co., Detroit, Michigan, U.S.A. (Brit. Pat., No. **196293**, April 12th, 1923. Convention date April 13th, 1922. Not yet accepted).—In a process of producing sheet glass in a con-

tinuous strip, a stream, p^1, of metal flows from a spout, a, on to
the surface of an endless band, c, and forms a pool, p, whence it
passes into the space, c^2, between the band and a roller, c^1. The
height of the space, c^2, is equal to the thickness of the sheet and
its width greater than that of the sheet, so that the pool of metal
remains unconfined in respect of its edges up to and through the
space. The flow of metal is regulated by gates, a^1, and is supplied
from the spout at the same rate as it passes under the roller, so that
the pool, p, is kept stationary. The width of the spout is narrow
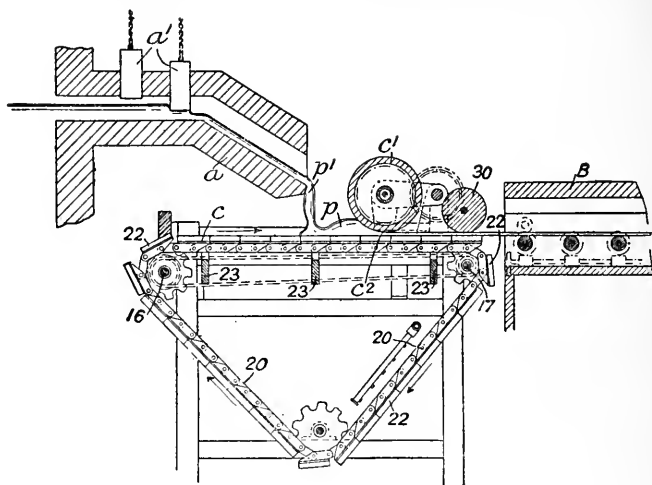
FIG. 143.

compared with the width of the strip of glass and the stream, p^1,
falls on to the pool and not directly on to the table. The table
consists of plates, 22, carried by the links of chains, 20, that pass
over sprocket wheels, and supporting-guides, 23. The shaft, 17,
of the forward sprockets is driven from another sprocket-shaft,
16, through a spring drive in order that the plates, 22, may be
pressed into contact with one another while they are passing
towards and under the roller, c^1. A roller, 30, may be mounted
between the roller, c^1, and the lehr, B, to smooth out any
irregularities that may appear on the upper surface of the glass
strip.   H. G. C.

296. Rolling Sheet Glass. CHANCE BROS. & CO., LTD., and
A. L. FORSTER, Smethwick, Staffordshire (Brit. Pat., No. **194441**,
December 23rd, 1921).—Glass rolling machinery, particularly for
rolling a sheet from a pot or charge of molten glass, is provided with
means for dividing the sheet into plates or portions of the required
length, and with means for importing an additional forward or
accelerated movement to the receiving table, each time a cut is
made, in order to carry the plate clear of the succeeding plate.
The machine comprises rolls a, b, which roll a charge of metal

into a sheet, h, in the usual manner, the sheet being received on a moving table, q. The cutting device consists of a roll, d, having a slot, e, which is entered by a blade, c, when the blade is dispersed by a toggle linkage operated by a compressed air cylinder m. The blade, c, is normally supported by a rest, g, clear of the glass sheet, but a catch, f, projecting from the end of the roll, engages the blade at the proper times and pushes it forwards, thus allowing it to be forced into the slot, e, and cut the sheet. The blade slides in slots in side frames, i, which swing about the shaft, l, of the roll, d. The movement of the blade by the catch, f, causes it to swing until withdrawn by the cylinder, so that it moves with the sheet while making a cut. In order to ensure that the blade is withdrawn from the slot, e, at the proper time, the frames, i, are formed with cam slots, o, that are engaged by rollers, p, carried by a fixed support.

The slots, o, are of such a shape that they lift the frame, i, until the blade is clear of the slot, e. The frame then swings back to its initial position. The table, q, which receives the sheet is

Fig. 144.

moved by a pinion which is driven from a shaft, u, Fig. 144, through a differential gear, v, w, y. In order to give an additional movement when the sheet is cut, a ratchet, 3, which engages a pawl secured to the toothed annulus, y, is reciprocated, thus moving the annulus and increasing the normal velocity of the gear train. The ratchet is oscillated by a reciprocating rack, 12, which is automatically connected with the driving-shaft when the cutting-blade is depressed and is released at the completion of its return stroke.   H. G. C.
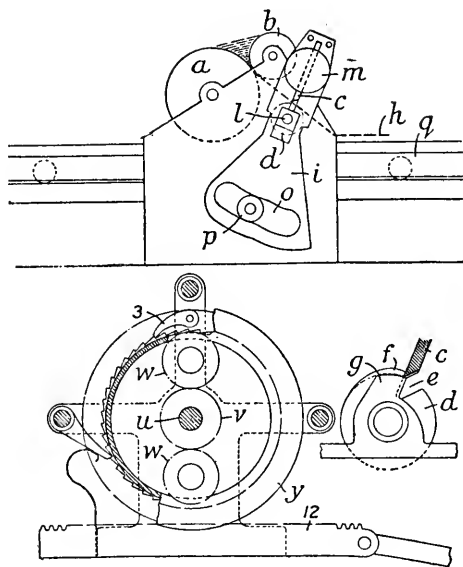
297. Method of Maintaining the Temperature of Glass during the Sheet Drawing Process. W. J. MELLERSH-JACKSON, London, and the LIBBEY-OWENS SHEET GLASS CO., Toledo, Ohio, U.S.A. (Brit. Pat., No. **194567**, April 4th, 1922).—In a process of drawing glass in flat sheets, the temperature of the molten glass which is to constitute the inner part of the sheet is raised by means of a heating element situated in the mass of glass from which the sheet is drawn. The heating element consists of a bar, 6, of refractory material wedge-shaped in cross section with its underside

flat or slightly curved. An electric heater, 9, embedded in the bar
enables its temperature to be raised. The bar is placed in the
drawing-pot, 2, with its upper edge horizontal and beneath the
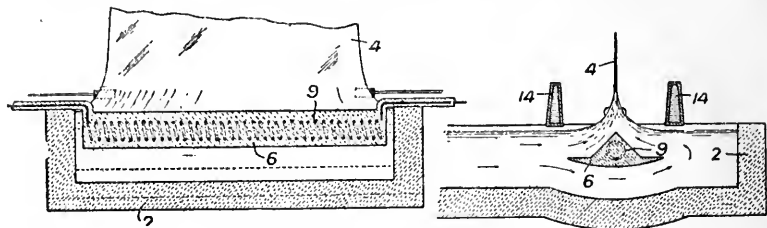
FIG. 145.

line of generation of the sheet, 4. The glass flows from the tank
beneath and around the bar, and the glass flowing into the interior
of the sheet is made more fluid. Water-coolers, 14, may be used
to stiffen the surface glass. In a modification, the bar, 6, is hollow
and is heated by gas.   H. G. C.

298. Temperature Regulation during Sheet Glass Drawing.
W. J. MELLERSH-JACKSON, London, and the LIBBEY-OWENS SHEET
GLASS CO., Toledo, Ohio, U.S.A. (Brit. Pat., No. **196175**, April 4th,
1922).—In a process of drawing sheet glass, the external faces of
the meniscus at the base of the sheet are heated in order to avoid
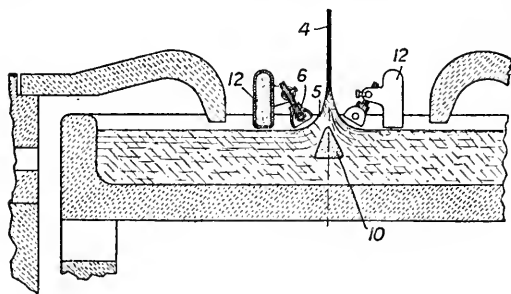
FIG. 146.

waviness of the sur-
face of the sheet. The
device, as shown in
cross section, may
consist of electric
heaters, 6, arranged
on each side of the
sheet, 4, opposite the
base of the meniscus,
5, which is formed
where the sheet is
drawn from the mass
of metal, the position
of the heaters being adjustable to enable the glass which forms the
surface of the sheet to be softened to the desired degree. The
heaters may be supported by the coolers, 12. In addition, a bar,
10, of refractory material may be arranged in the mass of metal
below the sheet. The bar slightly lowers the temperature of the
metal that flows into the interior of the sheet. In a modification,
the heaters may consist of slotted pipes from which gas jets issue and
play on the surface of the meniscus.   H. G. C.

**299. The Feeding of a Plate Glass Casting Table direct
from a Tank Furnace.** F. GELSTHARP, Tarentum, Pa., U.S.A.,
Assignor to the PITTSBURGH PLATE GLASS CO., U.S.A. (Brit. Pat.,
No. **192092**, January 23rd, 1923. Convention date January 23rd,
1922. Not yet accepted).—A process of forming plate or sheet

glass consists in causing the molten glass to flow by gravity from the tank through the space between cooled rotated rolls whereby the glass is rolled into a sheet. The apparatus comprises a pair of water-cooled rolls, 5, 6, which are placed close against a slot, 4, in the wall of a forehearth, 2, of a tank, 1, a lehr, 27, being arranged to receive the sheet, 28, as it emerges from between the rolls. A gate is provided to enable the forehearth to be shut off from
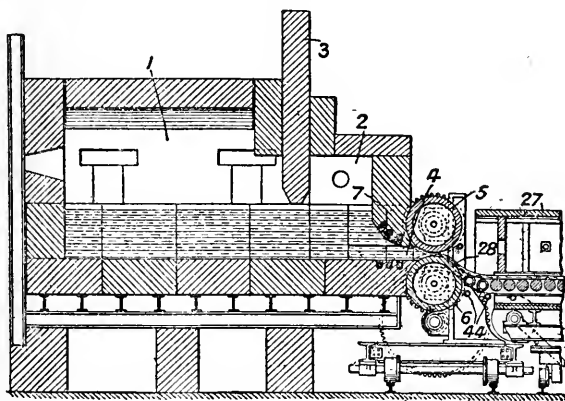
FIG. 147.

the tank, and electric heaters, 7, arranged in grooves in the wall of the forehearth, enable the temperature of the metal in the slot, 4, to be regulated. The rolls, 5, 6, and the lehr, 27, are mounted on wheeled trucks to enable them to be moved away from the tank. Burners, 44, are provided to reheat the sheet to overcome the chilling of the surface caused by contact with the rolls. In a modification, the slot, 4, is formed in the bottom of the forehearth instead of in the side wall. H. G. C.

300. The Casting of Glass direct from the Furnace. J. W. KUNZLER, Pittsburgh, U.S.A. (Brit. Pat., No. **192199**, November 7th, 1921).—An apparatus for casting plate glass comprises a rotatable cylindrical vessel, extending from and communicating with the melting tank, and having a longitudinal opening through which the metal is delivered on to the casting-table when the vessel is rotated on its axis. The device consists of a horizontal cylinder, 6, of metal lined with fireclay, which is fitted at one end with a flue, 22, and at the other end fits around a discharging nozzle, 3, formed in the side of the tank, 2. The cylinder is rotatably supported on rollers, 16, and has a longitudinal opening, 8. The casting-table, 9, runs on rails close below the cylinder, its direction of motion being at right-angles thereto. The roller, 11, is mounted on fixed standards, 14, alongside and parallel with the cylinder, its bearings being arranged to allow it to rise and fall freely. In operation, metal runs from the tank into the cylinder, and when

the proper quantity has entered, the table is started and the cylinder
is turned on its axis, so that the metal runs out of the opening, 8,
and is spread out in the front of the roller.   A block, 24, closes
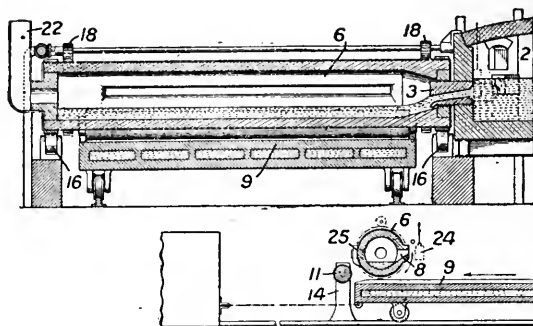
Fig. 148.

the opening, 8, while the cylinder is charging, and gas jets inside the
cylinder enable the temperature of the metal to be regulated.   A
smaller opening, 25, enables metal to be drained off when required
for making cullet.   H. G. C.

301. A Machine for Moulding Pottery. J. Benton, East
Palestine, Ohio, U.S.A. (Brit. Pat., No. **192886**, December 31st,
1921).—A machine for moulding a number of articles of pottery
simultaneously comprises a one-piece mould, 13, having a number
of pockets, 14 (Fig. 149), formed therein, and a plurality of circularly
arranged forming tools, 9, adapted to be moved into engagement
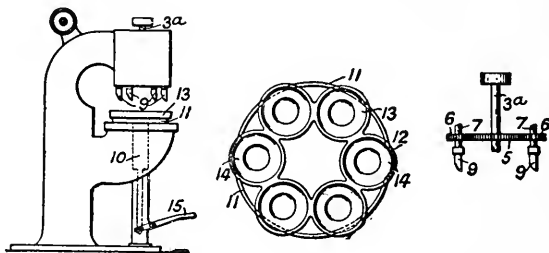
Fig. 149.

with   the   pockets   and   operated   simultaneously   therein.   The
tools, 9, are mounted on stub shafts, 7, rotated by a central
shaft, 3^a, through gear wheels, 5, 6.   The mould is brought into
engagement with the tools, 9, by means of an " underframe "
having an extension, 10, raised by a lever, 15.   The frame, 11, has an
upstanding flange with diametrically offset portions, 12, which
prevent rotation of the mould by the tools;   the latter may be
provided with detachable blades.   H. G. C.

302. The Design of a Glass Cutting Table. S. J. BARTLETT, Barry Dock, Glamorgan (Brit. Pat., No. **194045**, January 3rd, 1922).—In a table for cutting sheet glass one part is movable, so as to effect the severance of the glass after the cut has been made. The table-top is divided into two parts, 5, 6, the former being fixed whilst the latter is mounted so as to pivot about the point, 7, as shown in broken lines. The glass, G, is placed on the table, 6, whilst vertical, and rests on hooks, 9. The table, 6, is swung down and held by a spring catch, 18. The glass is cut in the usual manner, the cut being made in the over-hanging part, 24, and

FIG. 150.

parallel to the edge of the pivoted member, 6. The catch, 18, is then released, and the table, 6, raised about an inch by means of a lever, 10, and pull-rod, 16, so as to sever the glass at the cut.

H. G. C.
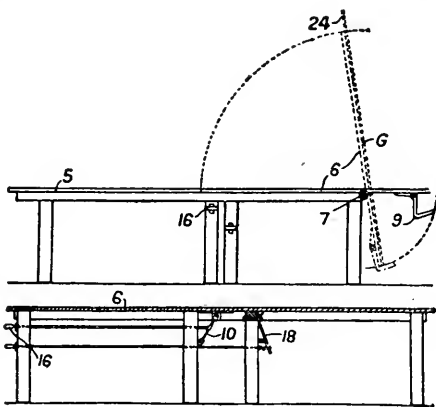
303. A Machine for Cutting Glass Tubing Continuously. NAAMLOOZE VENNOOTSCHAP PHILIPS' GLOEILAMPENFABRIEKEN, Eindhoven, Holland (Brit. Pat., No. **197937**, May 15th, 1923. Convention date, May 16th, 1922. Not yet accepted).—An apparatus for cutting continuously fed glass tubes into sections
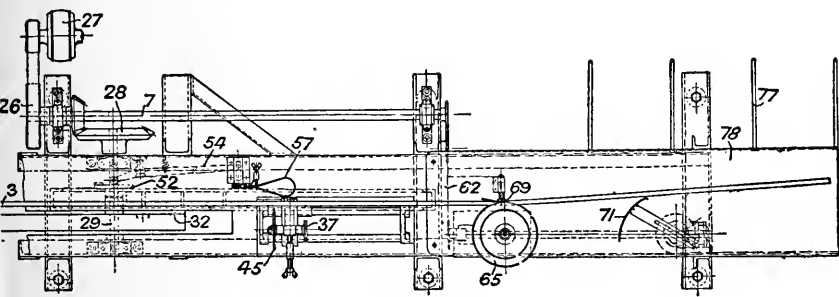
FIG. 151.

comprises means for bending the tube, during its travel, into contact with a cutter moving at the same speed and in the same direction as the tube, and means for breaking the tube by bending. The breaking may be assisted by suddenly cooling the tube at the point scored. The tube, 3, is scored by a disc, 45, revolved from a pulley, 37, by an electromotor, and axially reciprocated by a

15—2

cam, 32, on a shaft, 29, driven through gearing, 28, 26, from an electromotor, 27.   An adjustable resilient member, 57, is reciprocated across the direction of travel of the tube by a pivoted lever, 54, actuated from a cam, 52, on the shaft, 29, and bends the tube against the disc, 45, when the latter is travelling at the same speed as the tube.   The scored tube passes between a resilient support, 69, and a water-cooled rotating disc, 65, whereupon the tube is strained nearly to fracture.   An adjustable rotating transverse pusher, 71, driven from a shaft, 7, by a chain, 62, flexes the tube and completes the fracture.   The tube sections fall down an inclined table, 78, to a tray, 77.   H. G. C.

X.—Glass Accessories.

XI.—General.

304. Foremen Training in the Glass Industry. B. M. NUSSBAUM (*Glass Industry*, 1923, **4**, 63).—The slack period during the time of depression following the war was utilised by some firms (in America) for training their foremen in the basic principles of production, preparatory to the period when production would again be normal.   A plan was worked out, based on the idea of all-round development, selecting subjects of which the average foreman knew little, but which were considered to be essential to good works practice. Foremen were found in general to be ignorant of principles, such as specialisation, standardisation, elimination of waste, utilisation of resources, and the handling of men, being accustomed to work mainly on precedent or instructions.

The methods of training included (1) the use of text-books, (2) lecture courses, (3) problems calling for written solutions by the foremen, (4) group conferences for question, answer, and discussion. The text-books were specially drawn up, written in every-day language, and in this way discussed whatever was necessary in the treatment of mechanics, management, economics, psychology. At the Corning Glass Works, the course was comprised of six units, each unit consisting of about 140 pages of text, each to be studied in two weeks.   At the completion of each unit, a problem based on the text was to be solved and a lecture interpretative of the text was delivered.   Increased harmony between working heads, co-operation, better team work, better handling of men, developed interest, quickened responsibility, and closer relations between the foremen and the management were claimed as having been achieved as the result of the courses.   W. S.

305. The Importance of Pure Research on Glass in American Universities. ALEXANDER SILVERMAN (*J. Amer. Cer. Soc. Bull.*, 1923, **6**, 206).—The author referred to the vast sums spent on research by manufacturers of electrical plant, of metals, and particularly in Germany in connection with the dye industry. He pleaded that glass manufacturers through Manufacturers Associations should contribute grants towards the maintenance of pure and applied research in Glass Technology and suggested especially the endowment of fellowships at suitable Universities in America. A statement of many problems awaiting investigation was given. W. E. S. T.

306. The German Bottle Industry Since 1900. F. HILL-MANN (*Sprechsaal*, 1923, **56**, 56, 68, 79, 89).—At the present time, Schiller, and to a less degree Hilde and Wolf, machines were the chief semi-automatic machines employed. Of automatic machines the six-arm Owens was the most important, only two ten-arm machines having been installed. At Sazbach, 30 completely automatic Severin machines were in use, but these had an output of only 360 bottles per machine per hour. Dralle gave in 1908 a comparative chart of the cost of production for a factory producing 3 to 6 million kg. of bottle glass per year, but practice did not substantiate the whole of his figures. The amended figures were given in Table I.

TABLE I.

	Cost in marks per kg.			Percentage cost.		
	Hand.	Semi-automatic.	Six-arm Owens.	Hand.	Semi-automatic.	Six-arm Owens.
Batch	1·279	1·386	1·480	12·52	15·40	18·16
Fuel	2·425	2·078	2·425	23·73	23·19	29·75
Additional costs (moulds, etc.)	1·023	1·099	1·357	10·01	12·21	16·65
Management ...	0·741	0·741	0·741	7·25	8·23	9·09
Capital	0·823	0·740	0·576	8·05	8·23	7·07
Wages	3·928	2·946	1·071	38·44	32·74	19·28
Total	10·219	8·990	8·150	100·00	100·00	100·00

The relative costs were for the three processes, respectively, 100 : 88 : 80 and with an average selling price of 11·50 M. profits were 11·14 per cent., 21·82 per cent., and 29·13 per cent. Coal prices had varied in the following manner (per ton at Essen) :

Year.	1900	1903	1906	1909	1912	1915	1918	1920
Cost (M.)	10·10	9—	10—	10·5	11·25	13·25	24·3	106—192

For this reason coal had been largely replaced by lignite and where, before the war the glass industry used a total of 2,590,000 tons of coal (the bottle industry 655,000 tons), the consumption in 1921 was only 800,000 tons. The production of bottles slowly rose from 1904, when the figure was 500 millions, to 1907 with a

production of 530 millions. From this point it fell until in 1909 the output was only 84·4 per cent. of the 1904 figure. The effect of the introduction of the Owen's machine then made itself felt and the output rose to 600 million bottles in 1913. During the war a production of only 40 per cent. of the 1904 standard was attained. Two factors tending to limit production were (a) a steady increase of selling price (as shown in Table II), and (b) a fall in the consumption of alcoholic liquors.

TABLE II.

Average selling price in marks per 100 bottles of $\frac{3}{4}$-litre capacity.

1900	1905	1909	1912	1915	1917	1921
7·20	8·50	9·50	10·00	12·50	35·00	250·00

The export of bottles fell slowly from 1904 to 1907, more rapidly to 1909, when it was 61·1 per cent. of the 1904 value. It again increased to the war period, having a value relative to the year 1904 of 108·9 per cent. in 1912 and 104·4 per cent. in 1913. The proportion of exports to total production was 30·3 per cent. in 1904 and 23·3 per cent. in 1909. Most serious was the falling off from 1904 to 1909 of exports to England and America, but after the latter date the introduction of the Owens machine resulted in an increase of the numbers exported to these countries. The actual figures of exports to England and America (in million bottles) were :

<div align="center">1905, 123·9 ; 1909, 60·4 ; 1913, 150.</div>

The number of Owens machines in operation was as follows :

<div align="center">1905, 1 ; 1906, 22 ; 1908, 22 ; 1909, 55 ; 1911, 121.</div>

Table III gives the figures for the factories and employees in the whole of the glass industry in the years 1882, 1895, and 1907.

TABLE III.

	No. of factories.			No. of workmen.		
No. of workmen per factory	1882	1895	1907	1882	1895	1907
11 to 50	165	162	469	4,675	4,274	10,377
to 200	117	160	245	11,224	16,162	26,417
to 1000	30	57	100	10,057	19,312	38,112
Above 1000	1	3	4	1,544	5,495	6,215
Total	313	382	818	27,500	45,243	81,121

<div align="right">A. C.</div>

307. The Glass and Pottery Industry in Austria.   E. SELCH (*Sprechsaal*, 1923, **56**, 92 from *Neues Wiener Tagblatt*, 1923, No. 17). —Exports of glass from the old monarchy in 1913 totalled 86,726,680 crowns, whilst imports amounted to a value of only 9,594,143 crowns. Inner Austria, which now comprised the

Republic, contained only eighteen factories in 1919, amongst which was no plate glass works and only one small sheet-glass factory. On the other hand, Bohemia, Moravia, and Silesia had a total of about 150 works. The reason for this great inequality lay in the situation of coal, sand, and other supplies. The imports and exports in metric cwt. for Austria in recent years were :

	Imports.	Exports.
1920	172,009 cwt.	100,593 cwt.
1921	171,665 ,,	75,245 ,,

Of the imported glass the proportions coming from other countries were :

	1920	1921
Czecho-Slovakia ...	87 per cent.	89 per cent.
Germany	8 ,, ,,	10 ,, ,,

Exports were chiefly distributed amongst the following countries :

	1920	1921
Italy	32 per cent.	21 per cent.
Hungary	19 ,, ,,	33 ,, ,,
Jugo-Slavia	12 ,, ,,	21 ,, ,,

Recently four new factories had been built, two for sheet glass, and the import figures for the first nine months of 1922 showed a substantial decrease.

	Imports.	Exports.
Jan. to Sept. 1922...	73,442 cwt.	54,069 cwt.
Calc. total for year .	98,000 ,,	72,092 ,,

The saving on imports of 1922 over 1921 represented a value of seven million gold crowns.

Home supplies of raw materials such as sands and clays were now being exploited.   A. C.

308. Standardisation in the Glass Container Industry.
I. G. JENNINGS (*Glass Container*, December, 1922, **2**, 5).—A plea for co-operation between manufacturers, users, and the general public in the fixing of standard sizes and shapes. Containers of long and satisfactory sale and of trade-mark value were not to be lightly discarded. The aim of standardisation should be the efficient, economic production of those containers which conduced to the greatest sales of the material they contained.   V. D.

309. Variation of Bottle Capacities. (*Glass Industry*, 1923, **4**, 109. Abstracted from Bulletin No. 1009, U.S. Department of Agriculture).—In four-, eight-, and twelve-ounce bottles the respective average deviations from standard capacity were 0·12, 0·24, and 0·37 ounce in hand-blown ware, and 0·03, 0·06, and 0·18 ounce in machine-blown ware.

The following table had been drawn up from the weight variation allowed to blowers by manufacturers, and by use of the relation " 1 ounce of glass is equivalent to 3·1 drams in volume."

| | Calculated Maximum Variation in Volume. | |
Required capacity of bottles in fluid oz.	Individual bottles (fluid oz.)	Average of representative. Samples (fluid oz.)
½	0·10	0·014
1	0·10	0·014
2	0·19	0·027
4	0·24	0·034
6	0·24	0·034
8	0·29	0·041
12	0·29	0·041
16	0·39	0·056
24	0·39	0·056
32	0·58	0·083
64	1·16	0·17
128	1·94	0·28

Extensive measurements of the capacity of bottles and the volume of their contents indicated that only a small percentage of bottles, filled in accordance with good commercial practice, should vary in the quantity of their contents by more than the calculated maximum variations.   W. S.

Reviews.

Industrial Furnaces. Vol. I. By W. TRINKS. Pp. vii+319; Figs. 255 (London : Chapman and Hall, Ltd.; New York : John Wiley and Sons, Inc., 1923). Price 22s. 6d.

Messrs. Chapman and Hall publish in this volume a valuable companion book on furnace design to that by W. E. Groume-Grjimailo (see this Vol., REVIEWS, p. 159). The author, encouraged by the good reception accorded to a series of thirty articles by himself, and published during 1919, 1920, and 1921 in *The Blast Furnace and Steel Plant* and in *The American Drop Forger* under the title, " Heating Furnaces and Annealing Furnaces," has thoroughly revised and expanded the subject matter contained in the articles. The present volume embraces about half the series, and deals " with the fundamental principles and facts which underlie all industrial heating operations and furnace design, and with all those applications which are independent of the nature of the fuel on energy supply."

Most of the author's theories and calculations have been tested in actual furnace practice, and consequently his book offers the most valuable assistance to furnace designers in calculating the dimensions of various furnace parts. Where calculations have been made they are translated to diagrams and charts, and many dimensions, which the furnace designer has hitherto guessed, can, with the help of the charts, be determined rationally by brief reference. The calculations and diagrams appear to cover the whole of the important factors of furnace operation and design and render the academic work of extreme practical application. Although many of the diagrams appear at first sight to be cumbersome and complicated, the fact that their mode of construction is clearly explained renders them easily intelligible.

The introduction deals with the mode of use of heating furnaces, a general description and classification of types, and the elements of their construction. In the second chapter are discussed the factors which affect the heating capacity of various types of furnaces. Furnace efficiency, heat losses, fuel consumption, etc., occupy the third chapter. The consideration of the heat losses due to the capacity for heat of the furnace walls, radiation from the outer walls, escapes through furnace openings, incomplete combustion, and the loss in the products of combustion is supplemented in the fourth chapter by a discussion on heat-saving appliances of various kinds, including regeneration and recuperation and waste-heat boilers. In Chapter V, the strength and durability of furnace structures are considered, each part in detail, and, finally, Chapter VI is devoted to the movement of gases in furnaces, furnace pressures, and size and location of ports, flues, and ~~slacks~~. STACKS .

Although melting furnaces are not included within the scope of this work, the book should be in the hands of all glass manufacturers and glass-furnace builders, for it combines the theory and practice of heating furnaces in a most convincing manner, and, considering the paucity of good books on furnace design, will render their work easier and simpler, more certain in action, and more profitable.

It is a pity that such a valuable addition to furnace literature is handicapped by a poor index. F. W. H.

Refractories for Furnaces, Crucibles, etc. By ALFRED B. SEARLE. Pp. viii+170; Figs. 21+6 Tables (London : Sir Isaac Pitman & Sons, Ltd., 1923). Price 5s. net.

For the general reader this book provides a useful introduction to the subject of refractories. It briefly surveys the general properties of the principal refractory materials used in the metallurgical and glass-making industries without giving such complete information of the physical and chemical properties as would be necessary in a text-book for students' use. The author has adopted the novel arrangement of describing first of all refractories in the form in which they are used; leaving the consideration of the raw materials and the methods of manufacture to the later portion of the book. Closer co-operation between the user and manufacturer of refractories is very desirable, and a first step to this is the ascertainment of the precise conditions under which the refractories are used and the selection of materials which, from their intrinsic properties, are likely to withstand those conditions. The relationship between the refractory on the one hand and the various materials of the furnace charge on the other requires very careful consideration because of the complicated secondary products which may be formed, but if refractories are selected with due regard to their general properties and the conditions to which they will be exposed, many " failures " would be avoided. From this latter point of view the present book should be of service to furnace managers and foremen and can be recommended to them.

W. J. R.

I.—Glass-making Materials.

310. Estimation and Removal of Iron in Glass-making Sands. L. SPRINGER (*Glastech. Berichte*, 1923, **1**, 81).—Previous attempts to reduce the amount of iron in sands had not met with much success. The Badischen Anilin- und Sodafabrik, Ludwigs-hafen, had recently described a process as follows : " Washed sand without drying is covered with twice its weight of water, and 1 per cent. of concentrated H_2SO_4 added and well mixed. Then 1 per cent. of ' *Blankit* ' (which is essentially a reducing agent) is added and thoroughly mixed. In five or ten minutes the liquid becomes turbid and is run off. The sand is then washed with water two or three times and dried.'' Samples of Hohenbocka sand after treatment were whiter. By ignition, it turned to a weak yellow tint contrasted with the strong reddish-yellow of the ignited but untreated sand. Experiments on a Saxon grey sand failed to improve its colour. Analyses showed :

Kind of sand.	Before purification.	After purification.
Saxon	0.050% Fe_2O_3	0.040% Fe_2O_3
Hohenbocka	0.040% ,,	0.032% ,,

In the author's opinion, only the iron coating of the sand grains was removed by the Blankit or by treatment with HCl. This was of little use for the glass industry, but of more use for clay-working industries. Experiments were made to ascertain if calcination would materially improve the Saxon sand. An unwashed sample, ignited at 1,200° and analysed in a Bohemian glass techno-logical laboratory, showed only 0·02 per cent. of Fe_2O_3.

The author then carried out numerous experiments to verify or refute this apparently remarkable result. In particular, it was desired to find out whether a grade II sand containing more than 0·03 per cent. of Fe_2O_3 and suitable for making ordinary white glass could be converted by calcination to a Grade I sand containing less than 0·03 per cent. of Fe_2O_3. As a check on the author's analysis, sands were sent for analysis to other laboratories specialising in silicate analyses. Very conflicting results were obtained. Some results indicated that the iron content of a sand was reduced by calcination, and, moreover, that the loss was increased by increasing the ignition temperature. Some indicated that no appreciable good resulted.

Finally the Saxon sands calcined on a fairly large scale in a window glass glory hole at 1000° for five hours was used in a series of melting and decolorising experiments in a crystal glass furnace, but the results were unsatisfactory.

H. W. H.

311. Economic and Technical Advantages of the Use of Phonolith in the Glass Industry. R. PFLOCK (*Sprechsaal*, 1923, **56**, 355).—The " Deutschen-Erden-A.-G., Dresden," had succeeded in opening a phonolith bed in Central Germany, the percentage composition of which was : Loss on ignition, 2·26 ; SiO_2, 60·50 ; Al_2O_3, 20·30 ; Fe_2O_3, 2·99 ; CaO, 2·45 ; MgO, 0·08 ; K_2O, 5·06 Na_2O, 6·29. This was equivalent to the following mixture per double wagon-load : Sand, 12,000 kg. ; alumina, 4,000 kg. ; lime, 870 ; soda, 3,400 ; and, in the form of pure materials would have cost two and a half times the price paid for the phonolith.

W. C. S.

312. The Variation of the Moisture Content of Ammonia Soda and of Sodium Sulphate during Storage. DOROTHEA JAPHE (*Sprechsaal*, 1923, **56**, 393).—Tests were made on two wagon-loads, samples being drawn from the surface and from the bottom of the piles, and one test taken two weeks after the other. Further tests were made on samples 50 cm. below the surface of the pile. Apparently, the regular storage of the alkali in sacks was almost equivalent to direct exposure to the atmosphere, and the thorough mixing obtained prior to batch mixing created a very regular moisture content. Storage in large piles, however, could cause violent fluctuations from the mean moisture content; for example, 14·31 per cent. on the surface, and 2·7 more than 50 cm. below the surface. With piles of sodium sulphate, the moisture content varied from 6·08 to 4·24 per cent. at the surface, but remained steady between 0·25 per cent. and 1·3 per cent. more than 50 cm. below the surface.

W. C. S.

313. Potash in 1922. G. R. MANSFIELD (*Mineral Resources of the United States*, 1922, Part II, 87).—The great bulk of potassium compounds used in the United States in 1922 was imported from Germany, France, and Belgium. Only one of the American plants of which potash was the sole or principal product had survived, and that because of the manufacture of a valuable by-product. In all other plants, eleven in number, potash was a by-product. The home sources of supply were molasses distillery waste, steffens water from beet-sugar refineries, natural brines, and dust from cement mills and blast furnaces. No production was reported from alunite, silicate rocks, kelp, wool washings, or Nebraska or Utah salines.

A. C.

II.—Glass : Manufacture and Properties.

314. Large Scale Production of Electric Lamp Bulbs. G. GEHLHOFF (*Zeitsch. Verein. deut. Ingenieure*, 1923, **67**, 524).—An account of the manufacture of electric bulbs in Germany. Diagrams and tables gave the shape, dimensions, and names of the different portions of the crude bulbs used to make the two most widely used electric lamps in Germany and in America. One was pear-shaped and one spherical. The bulb walls had to be very thin and the wall at the body of the bulb was only 0·1 mm. thick.

The average percentage composition of the glass employed was SiO_2, 61·5; PbO, 23·6; Na_2O, 8·8; K_2O, 5·3; Al_2O_3 and Fe_2O_3, 0·8, and a batch which would give such a glass approximately was sand, 150; red lead, 59; soda ash, 37; and potash, 19·5, with a small amount of decoloriser. Cullet should have the same composition and must be washed if it had been lying in the factory for some time. Large cullet could be crushed with advantage. Bulb glass melted several times became hard and quick-setting on account of solution of alumina from the fireclay container. Cullet containing more than 0·5 per cent. of Al_2O_3 should be avoided and the batch should be free from alumina.

According to the author, melting in tanks had failed because, on standing, the glass separated into layers, the glass at the bottom being rich in lead and that at the top poor. Subsequent mixing was unavoidable, and so cords and seeds resulted.

Oval-shaped pot furnaces were used. Reducing flames had to be avoided as they caused deposition of metallic lead which quickly perforated or corroded the pots. Some pots had a capacity for 200—300 kg. of glass and supplied glass for bulb-making. Tubing and rod were made from other, larger pots (350—450 kg.). The furnace temperature need not be very high (1350—1400° sufficed). The type of furnace, type of producer and of fuel were not regarded as important.

The automatic production of bulbs was still held to be dearer and poorer in result than manual production, and all bulbs in Germany were still hand-made.

According to the size of bulb, up to ten workers gathered at each pot and up to five worked at a mould. In an eight-hour shift, one man could make about 600 good bulbs of average size and weight (about 60 gm.).

The bulb industry employed 4000 people, producing 250 million bulbs annually, and 80 per cent. of them were worked in Germany. Most of the red lead had to be imported, especially since the cutting off of the valuable lead mines in Upper Silesia. Attempts to reduce the lead content of the bulb glass failed because of the high standard of quality and appearance demanded and of the lower heating value of the coal gas used in the lamp factories. The soda content could not be increased to soften the glass, owing to the necessity for the storage and export of lamps.

All tubing and rod were still hand-made in Germany.   Rods for gas-filled high candle-power lamps were made of a hard glass, as they became strongly heated in use.   In this case, a special joining glass was fused between the rod and the pinch, for example, " Resistoglass," tungsten glass, or Jena 16$^{\text{III}}$.

Bulbs, tubing, and rod were not annealed, but the pinch after the fusing in of the leading-in wires, especially with high-power lamps, was sometimes subjected to a heating process.   H. W. H.

315. Progress in the Glass Industry. GUSTAV KEPPELEV (*Zeitsch. Verein. deut. Ingenieure*, 1923, **26**, 509).—The author reviewed the history and progress of the glass industry since the introduction of gas firing.   He dealt with fuel technology, machine technology, chemistry, and physics, under the sub-headings of hollow-ware, window glass, plate glass, grinding and cutting, refractories, raw materials, influence of composition on the properties of glass, and the need for further research and technical education. A list of Jena special glasses (excluding optical glasses) and dates of development was given.   The following table of compositions was set out :

Chief constituents of glass in percentages.

	Thüringian, poor.	Stas, 1868.	Kavalier. 1879.	Jena, before 1910.	Jena, 1911.	Nonsol, 1915.	Pyrex, 1915.	Jena new, 1920.
Silica	69·9	77·0	79·1	66·4	64·7	67·3	80·5	74·5
Boric acid ..	—	—	—	4·0	10·6	6·2	11·8	4·6
Alumina	—	—	—	2·4	4·2	2·5	2·0	8·5
Zinc oxide ..	—	—	—	6·2	10·9	7·8	—	—
Magnesia	—	—	—	5·2	—	3·4	—	0·1
Lime	3·8	10·3	7·6	—	0·6	0·8	—	0·8
Barium oxide	—	—	—	—	—	—	—	3·9
Soda	16·5	5·0	6·4	15·6	7·8	10·9	4·4	7·7
Potash	6·6	7·7	6·7	—	0·3	—	—	—

316. Glass as a Raw Material for Lighting. E. ZSCHIMMER (*Glastech. Berichte*, 1923, **1**, 73).—In a lecture delivered to the Lichttechnischen Gesellschaft, the various physical properties of lime silicates and borosilicates were discussed briefly, including those essential for the production of " Daylight " lamps.

In the discussion, complaint was made that opal shades were not regular in thickness or opacity, the rims being generally thicker than the centres, an error which was on the wrong side, since the more direct rays from the filament impinged on the thinner glass. There were also complaints of the numerous names given to opal glass.   It was suggested that lamp-makers should find a standard to suit them, and then co-operate with the glass-makers, who would thus have their working standard.   W. C. S.

317. The Analysis of Bubbles in Glass. J. W. HYDE and R. HUDDART (*Proc. Phys. Soc. Lond.*, 1923, **35**, 197).—Bubbles might arise in two ways, namely, by the generation of gas in the glass itself and by the introduction of air or furnace gases during ladling, pouring, or stirring.   In order to distinguish between the

two kinds, the gas was examined spectroscopically. The gas was liberated from the glass by heating pieces of the glass in a vacuum and pouring cold mercury on them. Bubbles due to the second cause contained nitrogen, whilst those due to the first did not.

J. R. C.

318. Thin Electric Bulbs. A. M. MONIER, Paris (Brit. Pat., No. **200050**, November 13th, 1922. Convention date, June 29th. Not yet accepted). — In the manufacture of electric lamp bulbs, without an apparent sealing-pip, a number of bulbs, a^1, a^2, are blown simultaneously in a mould, the blank terminating in cylindrical portions, c, d. An exhaustion tube, f, is fused on to the part c, which is then divided at the neck, b^1, from the blank, and formed into a bulb with the usual sealing-pip, as shown in Fig. 152. A glass neck, j, carrying a filament is inserted in the bulb a^1 and an exhaustion tube, k, fused on, as shown in Fig. 152. The bulb, a^1, is then parted from the blank at b^1, and exhausted and sealed. The bulb a^2 is then treated in a similar manner. By moulding several blanks at once, much thinner walls can be obtained than by blowing the bulbs singly.
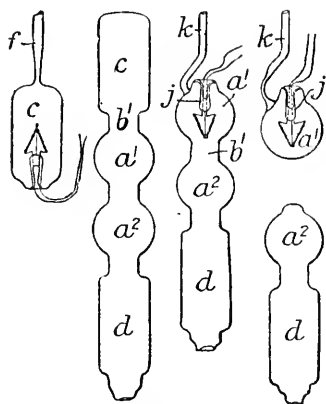
FIG. 152.

H. G. C.

319. Method of and Apparatus for forming Glass Tubes. KARL KÜPPERS, Aachen, Germany, Assignor to THE CHEMICAL FOUNDATION, INC., Delaware, U.S.A. (U.S.A. Pat., No. **1395963**, November 1st, 1921. Filed, May 19th, 1919, No. 298309).—The object of the invention is to provide glass tubes which are capable of resisting great pressure and are not liable to break. In carrying out the invention, a tube or similarly shaped wire net, c, is placed over a mandrel, a, of desired form, and a glass tube, b, slipped over the wire net. The tube, b, is closed at one end, a vacuum pump connected to the other, and, after withdrawing the air, this end also is sealed up. A ring, d, suitably heated, is slipped over the glass tube and moved up and down so that the whole of the tube becomes heated and is compressed against the wire netting and the mandrel, thus embedding the wire on the inside of the tube.
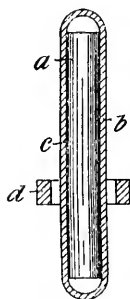
FIG. 153.

If it is desired to have glass on each side of the embedded wire, a glass tube is inserted between the mandrel and the wire net, after which the process is carried out as before.

S. E.

320. Making Bifocal Lenses. L. W. Bugbee and the Franklin Optical Co., Indianapolis, Indiana (U.S.A. Pat., No. **1451490**, April 10th, 1923. Filed, April 8th, 1922, No. 550843).— The invention relates to the method of making bifocal spectacle lenses in which a concave depression, 11, is ground in a piece of crown glass and polished, and a button, 12, of flint glass, having its underside ground and polished, is inserted in the depression and fused into place.
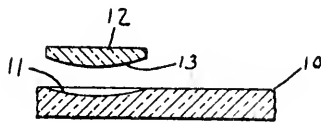
Fig. 154.

According to the specification, the definition of bifocal lenses made in this way is not as good as that of bifocal lenses made in other ways, due to strain introduced in the contacting surfaces produced by the polishing process. The invention consists in annealing the glasses after the grinding and polishing process, and then repolishing and fusing the glasses together as in the known process. Only a slight polishing is necessary after annealing, and the absence of strain in the contacting surfaces is said to produce a lens of definition superior to the known fused bifocals. G. D.

321. Claude Boucher. (*Le Verre*, 1923, **5**, 97).—An appreciation of the life and work of Claude Boucher and a short history of glass-making up to the time of the invention of his machines. E. M. F.

322. The Manufacture of Glass Marbles. C. J. Stahl (*Glashütte*, 1923, **53**, 356, 371, 403, 419, 435).—Hand-made marbles for use in sealing bottles, and those also internally decorated by coloured threads or spots, for use as toys, were produced from short cylinders of glass, usually 20 to 30 cm. in length. Rod for the first-named type was often made on a drawing-track, but the decorated glass was worked in smaller amounts. It was essential that the rod used for stoppers should be quite free from capillary tubes resulting from seed in the glass. Shaping the marble was accomplished by heating the end of the cylinder and applying to it special " marble-shears," consisting of two arms, on the end of one of which was fixed a hemispherical mould with four knife-like edges, and on the other a shearing blade. The end of the rod was pressed into the hemispherical recess and the shear arm so worked that the finished marble was cut off. Each heating allowed of the production of 4 to 10 marbles, and the output per man varied from 70 to 500 marbles per hour, according to size. The marbles intended for stoppers, after careful annealing, were sorted, smoothed on a sandstone wheel, and finally ground matt with moist fine-grained sand in a rotating drum. Methods of decorating toy marbles were clearly described. A. C.

323. Filter Plates of Sintered Glass. G. F. Hüttig (*Ker. Rundschau*, 1923, **31**, 394).—Porous filter-plates had been produced at Jena by sintering finely powdered and sieved glass. The

plates could be fused to glass articles of the same composition, forming suction filters, crucibles, etc. Several shapes and sizes of the articles were made of various glasses (Jena-apparatus, normal, Suprax, and Siolax) with five different pore sizes. Chemical attack on the apparatus glass with water, acids, dilute alkalis, solutions of salts and ammonia was small, but slightly greater with strong alkalis. The washability, rate of drying, change of weight in the atmosphere, and rate at which liquids could flow through were favourable to their use. Heating at 400° caused no appreciable loss in weight. The efficiency of filtration had been shown by the filtration of freshly precipitated barium sulphate. They had been used in quantitative analytical chemistry to determine Ag as AgCl, Ni as nickeldimethyl glyoxime, Hg as HgS and Hg_2Cl_2, Bi as Bi_2S_3, Sb as Sb_2S_3, K as $KClO_4$; to filter mercury, and to make special apparatus, such as Soxhlet extraction apparatus. Prof. Fresenius reported that he had obtained favourable results with the crucibles in quantitative analysis.   H. W. H.

324. Glass for Medical Bottles. H. KÜHL (*Glashütte*, 1923, **53**, 452).—According to the author, amber bottles of good mechanical strength and resistance to chemical attack could be made from a batch containing phonolith and in which salt-cake was employed instead of soda ash. The colour was obtained by reduction of the sulphate by the theoretical quantity of ground coal, whereby sodium sulphide was produced, this substance then reacting to produce iron sulphide, whilst the carbon itself also to some extent acted as a colouring agent.   A. C.

325. The Manufacture of Heat–resisting Glass. C. J. VAN NIEUWENBURG, Delft, Holland (Brit. Pat., No. **200020**, November 1st, 1922).—In the manufacture of thermo-resistant glass, lithium–alumino–silicate, preferably as lepidolite, is added to the ordinary materials, with the addition of a substance such as zinc oxide or boric acid compounds, which promotes the melting process. The glass produced has an increased tensile strength with a resultant increased coefficient of thermal endurance.   H. G. C.

326. On a New Shock– and Heat–resisting Glass. J. WOLF (*Sprechsaal*, 1923, **56**, 439).—The new glass, claimed by its inventor, Dr. Horak, to be unbreakable, and recently produced commercially in the form of apparatus and cooking vessels under the description " Resista " glass, was found to have the percentage composition : SiO_2, 78·94 ; B_2O_3, 13·50 ; Na_2O, 2·78 ; K_2O, 1·93 ; MgO, 0·97 ; Al_2O_3, 0·93 ; CaO, 0·28 ; Fe_2O_3, 0·47 ; TiO_2, 0·07. In essentials, therefore, it differed but little from the well-known Pyrex glass, having nearly 2 per cent. less silica and about 2 per cent. more boric oxide, and having also a small amount of magnesia. As one of the specimen cooking vessels broke in use almost immediately after purchase, the glass was not unbreakable, although other specimens showed it to be resistant.

Three batches were suggested for the preparation of the glass, namely :

(1) Hohenbocka sand, 100; Bohemian-felspar, 8; magnesite, 3; potash nitre, 5; cryst. borax, 20; cryst. boric acid, 20.

(2) Salesel kaolin sand, 100; phonolith from Bileri, 13·5; dolomite, 1·3; cryst. borax, 22·0; cryst. boric acid, 13·3.

(3) Sand, 100; potash nitre, 4·75; marble, 0·40; magnesite, 2·75; cryst. borax, 14·80; cryst. boric acid, 18·4; phonolith, 60.

<div align="right">W. E. S. T.</div>

327. The Soda Fusion as an Indication of Manganous and Manganic Ions. T. Schauer (*Sprechsaal*, 1923, **56**, 475).— In experimenting with a phonolith containing 0·30 per cent. of MnO and 3·60 per cent. of FeO, melts with fusion mixture in an electric furnace produced a cobalt-blue liquid, which on continued exposure to air turned bluish-green, green, and finally to a dirty brownish-green. A series of melts of MnO with varying proportions of FeO in fusion mixture gave always blue liquids, proving the colour to be due to the manganese only, and not to a compound of iron and manganese. When Mn_2O_3 or Mn_3O_4 were similarly fused, a bluish-green mass resulted. Compounds of MnO together with fusion mixture, when rapidly melted in a covered crucible, remained pure blue, but if kept molten long in contact with air they gave Mn_3O_4 compounds bluish-green in colour. Mn_2O_3 compounds, when rapidly fused, as well as when given a prolonged fusion, formed the bluish-green Mn_3O_4 compounds. Pure green melts containing quadrivalent manganese resulted from the soda fusion of MnO_2 and MnO_3, but, again, prolonged heating gave bluish-green Mn_3O_4. The Mn_3O_4 melts could be changed to the green MnO_2- and MnO_3-containing liquids by oxidation with potassium nitrate, whilst they could be reduced to pure blue MnO-melts by the action of carbon or of iron filings.   A. C.

328. Zirconia in Sheet Iron Enamels. W. F. Wenning (*Bull. Amer. Cer. Soc.*, 1923, **2**, 102).—The zirconia was used in place of alumina and silica in ordinary ground enamels. A replacement up to 10 per cent. by zirconia in the batch changed the working properties of the enamels very little, but big replacements rendered the enamel very viscous and difficult to melt down. Enamels containing up to 10 per cent. of zirconia were stronger and more elastic.

The chief virtue of zirconia was its opacifying property. White, amorphous zirconia, used as a batch ingredient to replace silica, alumina, zinc oxide, antimony oxide, stannic oxide, and phosphates, gave denser and purer enamels. When used in mill formulæ of low fluoride enamels, zirconia produced exceptionally good opacity and whiteness. Enamels containing zirconia were more acid resistant and also more resistant to mechanical and thermal shock than enamels without zirconia.   F. W. H.

329. The Purple Colour of Lamp Globes. M. Luckiesh (*General Electric Review*, 1917, **20**, 671).—The purple colour developed by radiant energy was shown conclusively to be due to

manganese, and this colour was quite unstable.   Curves were given
(Fig. 155) showing how large is the general light absorption in glasses

ML.—*Clear glass exposed to radiation from an arc lamp.*
MX.—*Clear glass exposed to X-rays.*
M.—*Purplish glass containing manganese.*
I.—*Blue-green glass containing iron.*
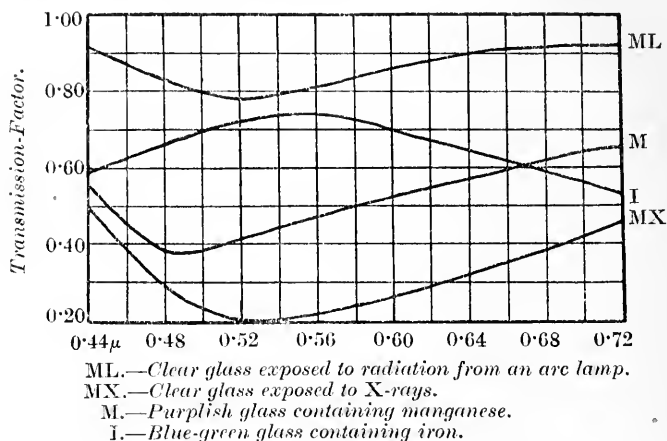
Fig. 155.

containing manganese.   The conclusion was drawn that it was
necessary to eliminate manganese for many illuminating purposes
and to be content with the possible green tint and the higher
transmission factor.   A. R. S.

330. The Density of Glass and the Process of Melting.
H. SCHALL (*Ker. Rundschau*, 1923, **31**, 293).—The decrease in the
density of molten glass with increase of temperature would appear
to prevent circulation and so to retard melting.   Actually circula-
tion did occur.   This was due to the escape of gas bubbles from
the top layer of glass, which accordingly became denser and sank.

Batch usually floated, but when filled into a very hot pot con-
taining only a little molten glass sometimes sank and adhered to
the base of the pot, subsequently becoming detached and causing
batchy metal.   To prevent this, a ladle of cullet should first be
filled on.   H. W. H.

331. Filament Composed of Basalt.   P. DHÉ, Paris (U.S.A.
Pat., No. **1438428**, December 12th, 1922.   Filed April 15th, 1921.
No. 461641).—The patent states that fine threads of basalt may
be used alone or in conjunction with others in the making of fabrics,
cords, cables, etc.   Such threads may be obtained by drawing
out melted basalt like glass threads.   After drawing they should be
maintained at 800° for some time, in order to give a devitrified
texture, which carries with it great flexibility.   S. E.

332. Cooling of Glass.   F. ECKERT (*Zeitsch. Verein. Deut.
Ingenieure*, 1923, **67**, 522).—An article dealing in a general way
with the annealing and hardening of glass.   The temperature
below which no further permanent strain could be introduced into

glass by heat treatment was given as 250—350°.   In the annealing of optical glass at the Sendlinger works, pieces of glass held in fireclay moulds were softened in a tunnel furnace, and then stacked in a thick-walled kiln and cooled at a prescribed controlled rate over a period of many weeks and even months.   A German cooking glass called " Durax " was mentioned.   Rolled or plate glass could be heated higher than most glass in annealing, as it lay flat in the furnace, but devitrification had to be avoided.   H. W. H.

333. On the Stresses in Cylindrical and Spherical Bodies due to Differences of Temperature Inside and Out.   CHARLES H. LEES (*Trans. Cer. Soc.*, **22**, 241).—The paper illustrated methods developed in some previous papers (*Proc. Roy. Soc.*, 1922, [*A*], **100**, 379 ; 1922, [*A*], **101**, 411) which showed that when a body of cylindrical or spherical shape was either hotter or colder at its surface than within, the stresses set up by the difference of temperature could be determined by a graphical method.
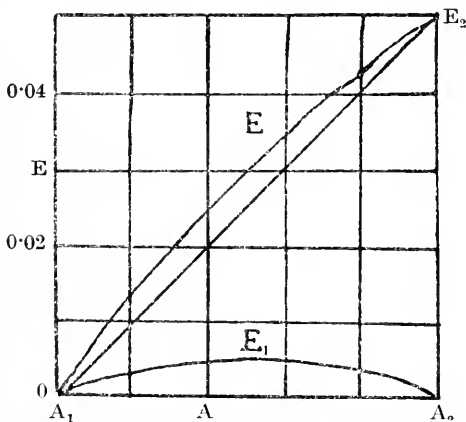
The actual (E), the mean and excess (E₁) expansion up to any section.   The numerical values to be multiplied by A₂—A₁.

FIG. 156.

The methods were applied to a hollow cylinder originally at air temperature throughout, but heated until its outside surface was at 1000° and its inside surface at 700°.

Graphs were drawn (1) with temperatures as abscissæ and volume dilatation as ordinates (Fig. 156); (2) area of section as abscissæ and excess of temperature over original temperature as ordinates (Fig. 157). From these, a dilatation curve was obtained by erecting ordinates at a number of points in Fig. 158 to represent at each point the dilatation of 1 c.c. of the material due to the rise of temperature at that point above the initial temperature (curve *D*).

The increase of volume of each element is obtained by multiplying a volume increment by the dilatation it experienced.   The increase of volume on expansion curve (Fig. 156) was thus drawn and its

final ordinate, A_2E_2, represented the total increase of the volume
of 1 cm. length of the given cylinder. If the cylinder had been
heated to a uniform temperature throughout the expansion curve
would have been the straight line joining A_1 to the end E_2 of the
expansion curve above A_2.

Dilatation of material.
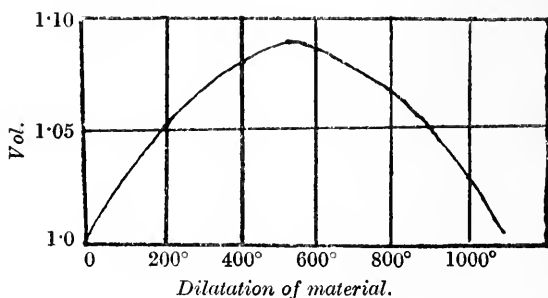
FIG. 157.

A uniform expansion would produce no stresses; the stress
might be measured by the excess of the expansion at each point
over the uniform expansion.

The paper further stated that the stress which an elementary
portion of shell exerts on its neighbouring portions might be expressed
in terms of the components of stress R along radial lines, T along
lines tangential to the circular section and X along lines parallel
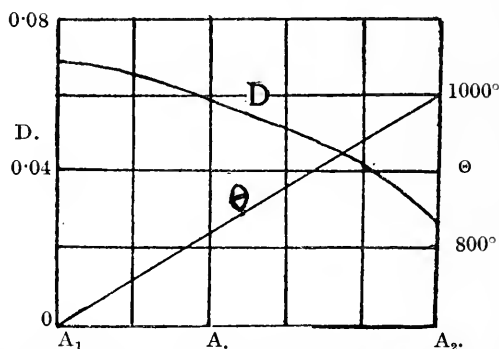
Θ *The temperature.*   D. *Dilatation throughout the section* $A_1 A_2$.

FIG. 158.

to the axis of the cylinder. Formulæ were given for the calculation
of these quantities (from the excess expansion curve). Young's
Modulus and Poisson's Ratio for the material were also involved
in the formulæ.

For a thin disc of circular shape the graphical work was identical
with that for the corresponding cylinder. In all the cases con-
sidered the stresses were those which existed under a non-uniform
distribution of temperature,   A. M. J.

334. Lichens, and the Deterioration of Church Windows.
ETHEL MELLOR (*Sorbonne Univ. Thesis*, pub. Librairie Générale
de l'Enseignement, Paris 1922).—Specimens of church window glass
which had suffered deterioration were iridescent and scaly, or
opaque and pitted.   Evidence of attack was found on both sur-
faces, and although the greatest alteration was to be seen on the
outer surface, yet signs of corrosion were sometimes first evident
on the inner surface.

The opacity sometimes extended over a whole surface, but
more often it took the form of more or less isolated discs.   These
often merged into one another, forming irregular patches.   The
glass at the centre of the discs gradually disappeared, forming a
small circular hole.   These pits grew, until they appeared as
circular or irregular cavities bordered by opaque glass, and lined
by iridescent scales, as seen under a binocular lens.   The maximum
width of such a cavity in the cases under examination was 5 mm.
and the maximum depth 1·6 mm.   Pits on the opposite surfaces
of glass sometimes deepened until the wall was pierced.   Micro-
scopic examination of the opaque glass revealed cracks and striæ,
somewhat resembling the marking of sand by waves, or discs
superposed, forming surfaces similar to geographical contours.

In some cases, the glass surface was not opaque and pitted,
but iridescent and scaly.   Under the microscope, this type of
corrosion exhibited numerous superposed spangles or plates,
varying in size, and sometimes striated.

Colourless, purple, blue, green, red, amber and amethyst glasses
were distinctly corroded ; greys were slightly more resistant, and
in some cases the yellow, silver-stained glasses were more immune.

The lichen flora of the windows existed, in the main, on the
exterior surface.   They flourished best on a glossy surface, with
little wind or sun, and the type depended to some extent on the
lichen flora of the immediate surroundings.   The interior surfaces
of windows were not favourable to the growth of lichens to any
extent.

Lichens were capable of growth on the slippery, glossy glass
surface, and they retained rain-water between their tissues and the
glass by capillarity.   The casing of lead round the glass was not
always well-fitting, with the result that rain-water was held in
a groove along the junction.   In any case, the slightest irregularity
in the edge of the leading induced the formation of small reservoirs.
The quantity of carbon dioxide normally held in solution by this
rain-water was considerably increased in the water retained by the
lichens and the lead, by absorption of that evolved by the lichens
during respiration.   Thus, the chemical change in the glass surface
was accelerated by the presence of the lichens, as shown by the
exaggerated deterioration along the line of a lichen growth.   The
attack was quite evident on glass which had been enclosed by lead,
and often it was very pronounced along the border of the leading.

The lichens penetrated the fissures in the opaque glass, and,
on growing, broke off the minute scales, incorporating microscopic
fragments in their tissues.   This mechanical removal of the opaque

glass produced pits and channels, which, under the microscope, were found to contain lichen *débris* after the decay of the living organism. The lichens followed the planes of separation in the glass, these resembling the cleavages of rocks.

The restoration of the leading, and the frequent inspection and cleaning of the glass were advocated to minimise the growth of lichens, and hence prevent the rapid corrosion of windows.

The paper was illustrated by numerous photographs.   V. D.

335. Lichens and their Action on the Glass and Leadings of Church Windows.   E. MELLOR (*Nature*, 1923, **112**, 299).—Portions of fourteenth century glass were still unchanged ; age did not appear to affect the corrosion.

The chemical change of the lead to the friable and unstable carbonate on exposure was of great effect. Apart from the liability of the lead to crumble and let the glass fall, such deterioration augmented the corrosion of the glass. The colour or chemical composition of the glass influenced lichen growth.

The application of a liquid mastic to exclude air and spores was advocated for reducing liability to corrosion.   V. D.

336. The Reduction of the Attack of Alkali Solution on Aluminium by the Addition of Water-Glass.   RÖHRIG (*Chem. Zeitung*, 1923, **47**, 528).—Seligman and Williams (*Met. Ind.*, London, 1922) had found that 5 per cent. sodium carbonate solution containing 0·05 per cent. of waterglass was without appreciable attack on aluminium at 75°.

The author now showed that although this protective action only held in the case of sodium hydroxide for a solution containing 0·5 gm. of sodium hydroxide and 0·5 gm. of sodium silicate per litre, it did hold over a wide range of concentrations, both at the ordinary temperature and at the boiling point, for sodium carbonate solutions and mixed sodium carbonate, and sodium sulphide solutions to which sodium silicate had been added.   W. C. S.

337. Estimation of the Surface Area of Glass-powder.   HANS WOLFF (*Zeitsch. angew. Chem.*, 1922, **23**, 138).—The surface of the powder was estimated by comparing the relative action of an alkaline solution on the powder and on a slab of the same glass, the area of which was known, and also comparable with that of the powder. Wolff found that in each case a point was reached at which the velocity of solution was not hastened by agitation. The solution used contained 145 gm. of sodium carbonate crystals and 25 gm. of caustic soda per litre, and a nickel sheet stirrer was used to agitate the liquid in a silver beaker kept at 95°. The glasses were passed between meshes 70 per cm. and 30 per cm., and calculations made on a 1 gm. basis :

$$\frac{\text{Surface of body (1 gm.)}}{\text{Measured surface}} = \frac{\text{Loss in weight of powder}}{\text{Loss in weight of plate}}.$$

Variations occurred due to irregularity in the shape of the powder, and also the hardness of the glasses.

Plates.

Type of glass.	Density.	Measured surface sq. cm.	Weight gm.	Loss in weight in 2 hrs.
Jena I	2·85	188·8	136·82	0·0964
			137·10	0·0982
Jena II	3·82	190·6	195·86	0·2308
			195·86	0·2308
Jena III	2·45	194·9	127·40	0·1304
Window glass	2·44	209·0	51·59	0·0866
			51·59	0·0866
Photographic plate	2·48	213·0	28·41	0·0708
			28·68	0·0632

Powder.

Type of Glass ...	Weight gm.	Loss in weight in ½ hr.	Calcd. loss in weight in 2 hrs. per 1 gm.	Surface of 1 gm. sq. cm.	Surface of 1 c.c. sq. cm.	Hardness.
Jena I	8·7089	0·3145	0·1444	282·8	730	1300
	8·3367	0·3441	0·1650	377·2	818	
Jena II	14·9987	0·8110	0·2460	203·0	776	1000
	8·6975	0·5782	0·2659	291·6	839	
Jena III	4·5711	0·2712	0·2372	281·6	690	1400
Window glass ...	11·5256	0·5280	0·1832	442·1	1050	2300
	2·1158	0·0866	0·1637	395·1	964	
Photographic plate	9·9636	0·3478	0·1396	420·0	1040	2300
	9·9636	0·3478	0·1396	470·5	1170	

W. C. S.

338. A Theory of the Structure and Polymorphism of Silica. R. B. Sosman (*J. Franklin Inst.*, 1922, **194**, 741).—According to W. H. Bragg and W. L. Bragg the atom-triplet structure was explained by means of a threefold hexagonal lattice, three triplets forming one unit of structure. Although two such structures were possible, this did not explain all the optical properties of quartz.

J. Beckenkamp's threefold prismatic lattice structure for low quartz, in which the nine atoms, that is, $3SiO_2$ triplets, formed a helix rotating upward to the right, satisfied the optical and crystallographic measurements.

The author assumed that the silicon atom shared one pair of electrons with each oxygen, and the oxygen atoms shared a pair of electrons between them. The silicon also shared one pair of electrons with each of two neighbouring silicon atoms. Thus, a silica " thread " was formed, with SiO_2 triplets as the unit. These threads formed in the liquid state, when they were in a state of vibration; the threads would not improbably have a helical twist in a drop of silica glass at a temperature of 1700—1800°.

A fall in temperature would result in less activity, until the structure of the mass of solid glass resembled a compressed pad

of wire. Drawing into tube or rod would disturb the thread arrangement, explaining the difference observed between the expansion parallel to, and perpendicular with the axis of rods and tubes, and the variation in different samples. The condensing of amorphous silica in fine fluffy form, and the formation of fibrous glass also followed.

In the author's view, the three forms, *cristobalite, tridymite,* and *quartz,* were built up by a combination of the threads in different ways. The threads were linked up through oxygen atoms, and the crystal structures were maintained by two restraints, (1) the connections of the silicons in threads, and (2) the attraction between the outer ends of oxygen atoms belonging to different atom-triplets.

High *cristobalite* was of an external cubic symmetry, the threads being straightened out, whilst high *tridymite* assumed an external hexagonal symmetry, the threads parallel to the hexagonal axis, but shrunken longitudinally. *Quartz* was of a trigonal external symmetry, with silicon atoms nearer together, and the oxygen atoms in vertical pairs, being right- or left-handed.

The high-low (α—β) inversion in all the crystalline forms was similar, and all inversions showed a " temperature hysteresis." The inversion temperature was roughly inversely proportional to the volume of the low form ; hence the high-low inversion mainly affected the outside linkings of the oxygen atoms. Rise in temperature increased the vibration amplitude of two oxygen atoms, and at a certain temperature an unstable state arose, when these atoms took up new positions to give the high form.

At a temperature of 573°, a sudden change in the oxygen grouping of low-quartz brought the oxygen atoms into vertical pairs all equidistant from the axis of the thread, forming high-quartz.

A rise in temperature to 117° changed the oxygen arrangement in the *tridymite* structure, as they were further apart than in *quartz.* The high-*tridymite* had two forms, with inversion at 163°. The two forms resulted from the possibility of two types of association of oxygen atoms, since the radial distance between them was nearly the same as their axial distance. In quartz, they were definitely associated in pairs.

The variable inversion temperature of *cristobalite* was accounted for by an incomplete oxygen structure, some of the triplets vibrating or rotating about the thread. Low-*cristobalite* had an average oxygen distance intermediate between those of *quartz* and *tridymite.* The oxygen pairs were spaced varyingly ; hence the variable inversion. This assumption of atoms not in geometrically defined positions in a crystalline substance was presented, pending further experimental results.

The solidity of silica glass was dependent on the entanglement of long silica threads, and to a smaller extent on the inter-relation of oxygen atoms.

In order to explain the partial change of chalcedony into *quartz* and *tridymite* below 870°, as observed by Fenner, it was assumed to have a sub-microscopic, fibrous mixture of quartz threads and amorphous threads.

Slight rearrangements of the quartz thread groups together with the presence of variable small quantities of water accounted for the various optical properties of *quartzine, lutecite,* etc.

The thread hypothesis was extended to silicates. The three forms of Al_2O_3, SiO_2, *cyanite, sillimanite,* and *andalusite,* closely resembled the three forms of silica. Potash felspar ($KAlSi_3O_8$), magnesium metasilicate ($MgSiO_3$), and other silicates exhibited the same type of slow polymorphism.

The titanates, germanates, zirconates, and stannates showed analogous polymorphism, but data relating to the oxides TiO_2, GeO_2, ZrO_2, and SnO_2 was incomplete.

The structure accorded to silica accounted for many phenomena, including the minimum in the temperature–volume curve of silica glass, the relations between the specific heats of the crystalline forms, and the effect of surface and of twinning on the conversion of *quartz* into *tridymite.*   V. D.

III.—Lamp-worked and General Scientific Apparatus.

339. A Mercury Vapour Pump. L. T. JONES (*Optician*, 1923, **66**, 198).—The pump shown, constructed of Pyrex glass, was stated to function as other pumps of similar type when the pressure was reduced to 0·1 mm. or less. It was of robust construction and not exceedingly difficult to make, one of the most difficult parts, the sealing of the air inlet through the jacket to the inner tube, being relatively easy if the annular space between the two tubes was made about 2 mm. The small hole through which the mercury returned from the condenser to the reservoir should be about 1 mm. diameter. The jets through which the air and mercury vapour were carried were twelve in number, each having a diameter of about 0·5 mm. The apparatus was best constructed from the top downwards, the bulb being blown last. When properly heated, the flow of mercury was such that about 3 cm. were left in the condenser, thus sealing the small opening at the bottom.   M. P.
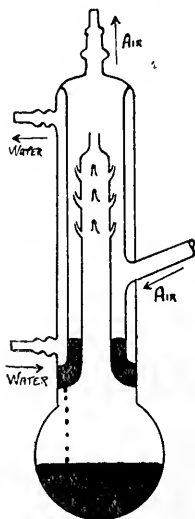
FIG. 159.
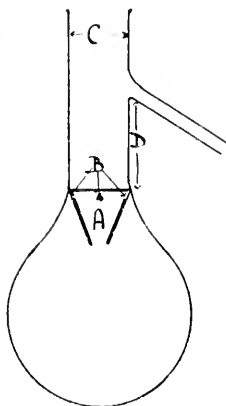
340. A Modified Classen Flask. G. A. COLLINSON (*Chem. and Ind.*, 1923, **42**, 1109). —The flask was pear-shaped and had the construction shown, its dimensions for the 200 c.c. size being, *C* 2·5 cm. diameter, *D* 7 cm., the small holes *B* 1·5 mm. diameter and the orifice of the cone, *A*, about 9 mm. The small holes should be as near the point of fusion of the cone to the flask as possible. The chief disadvantage was stated to be the difficulty of extracting broken pieces of capillary from the bulb, but this was to a large extent minimised by using thick-walled capillary to admit air during distillation. The apparatus functioned satisfactorily at pressures down to 10 mm.

FIG. 160.   M. P.

IV.—Decorated Glass.

341. Ornamenting Glass by the Double Transfer Process. J. J. WILSON, Sutton Oak, and W. WILSON, Cowley Hill, both in St. Helens, Lancashire (Brit. Pat., No. **199623**, July 22nd, 1922).— Relates to double transfer processes for decorating the back of glass or other transparent or semi-transparent material to show through at the front. The design on the original transfer is covered on the side remote from the paper with a protective coating of gold leaf or enamel, which, after the second transfer to the back of the glass, etc., forms a backing. A final backing of paint or silver may be applied.   H. G. C.

342. The Manufacture of Decorated Glass Panes. (*Diamant*, 1923, **24**, 311).—The glass was decorated by fusing glass-grains into the sheet. In order that the pattern might be produced with a well-defined border and without distortion, the glass was first poured and rolled. The chosen colourless or coloured glass grains were fastened with an adhesive on the surface of paper, fabric, or other easily burnt material, and while the sheet of glass was still in a plastic state the sheet of paper or fabric containing the glass grains was pressed on to it. The organic matter was burnt by free access of air and the ash brushed away in the annealing furnace. The surface was cleaned after cooling in an acid-bath.
                                          E. M. F.

343. Engraving on Glass with Gelatin. (*Diamant*, 1923, **25**, 231). Compare this JOURNAL, 1918, Abs. No. 236.—The use of gelatin solution to produce frost patterns on glass was particularly striking when salts such as sodium thiosulphate, potassium chlorate, potassium nitrate, or alum were added. Very fine

crystalline plant designs then appeared. The designs were very seldom alike. The method formed a cheap commercial process for the decoration of all kinds of ware. The sheet of gelatin should be laid on as smoothly and evenly as possible, be free from air, and be dried at a temperature not exceeding 40°.

E. M. F.

344. Method for Producing Raised Designs on Glass. G. L. Huysmans, Château de Brusthem, Brusthem lez St. Trond, Limburg, Belgium (Brit. Pat., No. **199802**, March 28th, 1922).—Raised designs or inscriptions are produced on glass, pottery, and the like by the application thereto of a plastic composition consisting of finely powdered metals, such as copper, aluminium, and magnesium, mixed with an emulsion of carbonate of calcium, a thick solution of mucilage such as Senegal gum copal, aluminium sulphate, and coal tar or drying oil. The composition hardens without high temperature baking. A suitable method of applying the composition is by extrusion apparatus. The leads of stained glass may be imitated by this process. H. G. C.

345. Metallic Lustre Etching for Glass and Porcelain. (*Diamant*, 1923, **19**, 249).—A mixture of one part by weight of silver chloride and five parts by weight of unburnt clay was smeared on glass and burnt in at a low temperature. The clay was washed away and the glass heated in a reducing flame. This treatment produced a translucent, greenish-brown, gold-lustred surface, whilst after the first heating the glass showed only a yellow tinge. When ochre was substituted for clay, a variety of bright colours was produced. One part of silver chloride to twenty parts of clay produced a translucent amber-yellow. The correct period of time for heating to obtain the desired result was judged by experiment. Five to eight minutes were usually sufficient. Strong heating or prolonged action gave a matt metallic surface.

The colour and strength of the lustre depended on the composition of the silver mixture and also on the silver salt used. Silver sulphate gave a yellow colour with little metallic lustre, silver chloride a green colour with a gold sheen, and silver sulphide a yellow etching. The silver mixture used should not be made richer in silver than one part of silver oxide to three parts of the inert substance. E. M. F.

346. The Metallic Coating of Glass and Ceramic Ware and the Glazing of Metal Ware by Spraying. J. Barfuss (*Glashütte*, 1923, **53**, 436, 451).—In modern forms of apparatus for coating glass and ceramic ware with a metallic film, the metal, in the form of wire of suitable gauge, was melted by the production of an electric arc. As the tip of the wire melted, the fluid metal was projected on to the article to be coated (the surface of which was ground smooth) by a jet of air under pressure. An automatic adjustment fed in the wire at the rate at which it was used. The process could be used for metals or alloys such as brass, and an alloy of the percentage

17—2

composition bismuth 44, lead 28, tin 16, cadmium 12, having a melting point of only 54—64°, could be used, greatly economising current. Metal and stone goods were coated with a glaze by the same machine, using rods of glass, for which purpose a special glass of low melting point, containing 3—5 per cent. of lead silicate, was employed. Metal ware was also coated with a glaze by projecting powdered glass by means of a blast on to the red hot surface of the metal. A gold ruby glaze for this purpose consisted of a mixture of potash-lead glass with purple of Cassius in the proportions of 1 lb. of the former to 1 gm. of the latter. For glazing earthenware a process was adopted whereby the surface of the ware was heated by a carbon arc and powdered glaze sprayed on to the hot surface. A suitable glaze consisted of clay, limestone or gypsum, and a large proportion of granite.   A. C.

347. The Preparation of Marbled Glass. OTTO W. PARKERT (*Sprechsaal*, 1923, **30**, 312).—Marbled glass produced from mixed broken glass had little mechanical strength and fine hair-cracks appeared at the junction of the different coloured pieces of glass.

The use of lake and spirit colours was not satisfactory, as the temperature conditions had to be watched too closely.

Marbled glass could be produced by the use of a vitrifiable pigment. The glass article, made of the best colourless crystal glass, was painted on one side with a pigment mixed with gum arabic and borax, grained as desired, and burnt at a low temperature. In the case of illuminating ware, a second coat of enamel (usually white) was given to produce an opal effect.

A cheap marbled glass was obtained by direct means by melting 100 parts of sand, 3 parts of salt-cake, 4 parts of iron oxide, 12 parts of graphite or charcoal, 36 parts of soda and 12 parts of lime and potash. This crude black glass was gathered in layers, one over another, worked up into buttons, beads, or similar articles, and decorated by mixtures of metallic salts. For example, a dark green effect was produced with 1 part of silver sulphide and 5 parts iron ochre; a bright brown with 1 part of silver sulphide and 5 to 10 parts of manganese dioxide; bright or dark brown with 1 part of copper oxide and 1 to 3 parts of ochre The colours were mixed with water, and after painting on with a paint-brush, the article was heated to a dull red heat.

Marbled glass was produced also by the use of ground coloured glass, agglomerated by the addition of water-glass solution, or by mixing with borax and lead-glass powder and heating in the furnace. The article formed was often painted with a phenol-resin varnish which was resistant to heat and to normal wear.

E. M. F.

348. Cameos. WILHELM HANNICH (*Ker. Rundschau*, 1922, **30**, 36).—Up to the last quarter of the nineteenth century cameos were made from sifted glass paste or enamel. Moulds were made by mixing finely powdered rottenstone with water to a kneadable paste and placing it in an iron ring. A model made of wood, glass, etc.,

was pressed into the paste and the edges were trimmed off. The model was withdrawn when the mould had partly dried, and was thoroughly dried. The glass was placed on the mould, on a fireclay slab, and melted in a muffle furnace. When the glass had become softened, the plate was withdrawn and the glass pressed into the mould. It was then reheated and cooled in a special chamber or in the muffle furnace itself. After removal, the pieces could be still further worked by cutting.

For two-coloured cameos the relief was made of hard glass, and mounted on a plate of soft glass. The sides to be stuck together were ground, polished, and combined by a flux the composition of which might be 2 parts of sand, 6 of red lead, 2 of saltpetre, 3 of borax, and 6 of bismuth oxide. To protect the relief during the heating, it was covered with a paste of chalk which had to be dry before the introduction into the muffle. To know when the flux fused, some was placed in a small dish beside the object. Such processes were still troublesome and slow, and only recommended for special purposes.

Black and other coloured plates were pressed from glass. Figures were also pressed from glass, the edges being turned towards the bottom by the mould. Both plates and figures were ground on the side to be cemented by an iron disc with the addition of water and sand and planed on a grindstone. The surfaces of both the iron disc and the grindstone had to be kept free from hollows by trimming with carborundum. If plates were left matt, a larger production was obtained. Only small figures up to 30 mm. diameter could be produced by pressing. Larger pieces bent easily and did not lie down in the mould.

The figures were often silvered, gilded, or made iridescent. Blue and rose plates with white figures, and black plates with blue or violet tinted figures were used.

Glass with curved surfaces served as a variation. Spheres were blown in the glass-house and cut in watch-glasses by a diamond mounted on a crank. The cut surface and the surface to be cemented were ground until the pieces were quite thin. Pieces of diminishing size were then cemented one on another and a figure of the same or different coloured glass was mounted on the top.

H. W. H.

V.—Optics and Optical Instruments.

349. Two New Methods of Measuring Internal Diameters of Transparent Tubes. J. S. ANDERSON and G. BARR (*J. Sci. Instr.*, 1923, **1**, 9).—The first method described was an immersion one in which, having adjusted the liquid roughly to the same refractive index (for some wave-length within the visible spectrum) as the glass, equality of index was obtained by altering the wave-

length of the light. Monochromatic light was passed through a constant deviation spectrometer and the beam rendered parallel by a lens placed in front of the cell in which the tube and liquids were immersed. The tube was observed, when of normal bore, by a travelling microscope, and when of very fine bore by a microscope with micrometer eyepiece. Having made the rough adjustment of the liquid, the microscope was focussed on a plane a little behind or in front of the edge of the tube and the wave-length varied until the dark band seen (due to the fact that the microscope was focused in a region in which there was no light) just disappeared. If, in attempting to get equality of index, increasing the wavelength up to the limit of the visible red only decreased the width of the dark band but did not cause it to disappear, the liquid of next lower refractive index would be the one to use.

This method enabled equality of index to be made to an accuracy of 0·0001 or less, and as it was shown that for small differences in refractive index the numerical percentage error in the measured radius, r_1, of the tube was equal to the percentage error in the index, the radius could be measured with great accuracy.

The following table gives a list of liquids suitable for use :

Liquid.	Ref. Index.	Liquid.	Ref. Index.
Menthyl acetate	1·448	Methyl salicylate	1·539
Carbon tetrachloride ..	1·463	Nitrobenzene	1·555
Liquid paraffin	1·474	Benzyl benzoate	1·570
Toluene	1·497	Aniline	1·587
Benzene	1·503	Carbon disulphide	1·630
Ethyl iodide	1·516	α-Bromonaphthalene ..	1·660
Ethyl salicylate	1·525	Methylene iodide	1·740

The cell in which the sample was immersed should have all cemented edges protected from the solvent action of any of the above liquids by being treated with a coating of bichromate jelly. Long tubes could be dealt with by incorporating into the bottom of the cell a tube just wide enough to allow the specimen to slide through it and closing the interspace by means of a rubber tube, as in the case of an ordinary Liebig condenser.

The second method of measurement consisted in placing an X-ray plate immediately behind the tube, the bore of which was filled with an opaque substance, for example, mercury, and exposing it at some distance, say 2 metres, from an X-ray bulb. Allowance could be made for the divergence of the beam by taking at the same time a photograph of a rod of known dimensions and measuring the relative widths of the shadows obtained. Measurements were better made on the negative than on a print.

Whilst the first method was more convenient for many purposes, the second gave a permanent record of the diameters of the tubes, and, further, was not dependent on the degree of homogeneity of the substance of the tube.   M. P.

350. A Simple Method of Determining the Focal Lengths of Thick Lenses and Combinations of Lenses. F. G. Smith (*Optician*, 1923, **65**, 185).—In this method, there were three oper-

ations : (a) an object was viewed through the lens by a telescope focussed on infinity, so that parallel light emerged from the lens; (b) the object was focussed by the lens on another object at a convenient distance from the first; (c) both objects remaining stationary, the lens was now moved to the conjugate position, so that the first object was again in focus on the second. If the position of the lens on the optical bench was observed each time the focal length could be calculated, being equal to the square root of the product of the length ab and the length ac. The method could be applied to converging and diverging lenses, diagrams being given to illustrate the application.   J. R. C.

351. Historical Note on the Spherical Aberration Coefficient. A. WHITWELL (*Optician*, 1923, **65**, 358).—The expression for the aberration derived by Robert Smith in a book published in 1738 was shown to be the same as that derived by Henry Coddington in 1829 and followed by later authors. J. R. C.

352. Improved Temperature Control for the Pulfrich Refractometer. T. M. LOWRY and R. G. PARKER (*J. Sci. Inst.*, 1923, **1**, 16).—The improvements consisted in the provision of much wider inlet and exit tubes for the circulating water and the additional use of a water-jacket on three sides of the liquid under examination. Tests showed that at the same pump speeds the flow of water, even with the added resistance of the extra jacket, was almost twice as great in the new English pattern as in the Zeiss one. Tests were made on both instruments to determine the difference in temperature between the liquid under examination and the heater. With a room temperature approximately 9° below that of the circulating water, the error in measurement of refractive index corresponded with a temperature error of 0·17°, 0·16°, and 0·27° for benzene, toluene, and ethylene bromide, respectively, in the case of the new instrument, whilst for the old pattern the errors were twice as great. By measuring the temperature of the circulating water and that of the top of the prism, using platinum resistance thermometers, the linear relationship between the errors and the temperature difference between the air and the circulating water was established and the error found to be 0·044° per degree difference. This was 50 per cent. greater than that found directly from the refractive indices of ethylene bromide and the difference was attributed to the fact that the platinum spiral was separated from the prism by a layer of paper which was absent in the optical experiments.   M. P.

353. Crookes' Anti-Glare Glasses. J. H. GARDINER (*Trans. Optical Soc.*, 1923, **24**, 102).—In a brief note the marketing of the glasses, which originated through Crookes's researches on glass-makers' cataract, was traced to its present position.

In a discussion, L. C. Martin stated that investigations by himself and others had led to the result that only radiations of wave-length shorter than 0·305 μ, on the ultra-violet side, injuriously affected

the eye. Protection against sunlight and ordinary artificial light was therefore unnecessary.

H. H. Emsley stated that Crookes's work showed that it was the infra-red radiation that caused glass-makers' cataract.   J. R. C.

354. The Theory of Toric Spectacle Lenses. A. GLEICHEN (*Optician*, 1923, **65**, 52, 125).—A continuation of the mathematical discussion to which reference has been made previously in this JOURNAL (Abs. No. 356, 1922, and No. 42, 1923). The mathematical relations deduced were applied to the solution of numerical examples. The astigmatism of toric lenses was also examined and the conditions for its elimination were derived.   J. R. C.

355. Recent Developments in Spectacle Lenses. W. A. DIXEY (*Trans. Optical Soc.*, 1923, **24**, 72).—The most prominent developments were stated to be (*a*) the use of a filtering glass to absorb injurious rays, and (*b*) the provision of so-called periscopic lenses. Different investigators had arrived at different results when examining the best form of lens, and six conditions were enumerated which precluded an exact result. The main class of aberration affecting spectacle lenses was radial astigmatism. The author discussed how this might be corrected by modifying the form of the lens.   J. R. C.

356. Methods for Machine Calculation of Rays through a Lens System. C. W. WOODWORTH (*J. Opt. Soc. Amer.*, 1923, **1**, 673).—Three methods, each of which was illustrated by an example, were given; one for edge and oblique rays, a corresponding method for paraxial rays, and the direct calculation of the power of a lens. Simple arithmetical operations suitable for machine calculation were substituted for the usual trigonometrical formula.   J. R. C.

357. Large Telescopes. F. DYSON (*Trans. Optical Soc.*, 1923, **24**, 61).—This presidential address to the Optical Society dealt with the uses to which these instruments were put. The development of large reflectors was first traced. At first, the mirrors were of speculum, but after Liebig's discovery they were of silvered glass. They had been largely used for photographing nebulæ and distant stars. The largest was a 100-inch reflector at the Mount Wilson Observatory. The increase in size of refracting telescopes was also traced to the objective of aperture 40 inches and focal length of 62 feet at the Yerkes Observatory. Their main work had been the visual discovery of small planets and satellites and measurements of their movements and for the photographic determination of velocities by the displacement of spectral lines.   J. R. C.

358. The Astronomical Telescope and Ametropia. E. MAYER (*Optician*, 1923, **65**, 167).—It was shown that the magnification produced by the astronomical telescope was less for a myopic eye than for a hypermetropic eye, as with a Galilean telescope. The variation of the magnification depended on the power of the eye-piece and not on that of the object glass. The question of designing telescopes and prism binoculars for abnormal eyes was mathematically examined in detail.   J. R. C.

359. A Simple Method of Measuring Colour. A. E. O. MUNSELL (*J. Amer. Cer. Soc.*, 1923, **6**, 777).—The author emphasised the importance of clear definitions in dealing with colour measurement. The Munsell system attributed to colour three dimensions, hue, value, and chroma. Hue was that quality which distinguished a red from a yellow, a green from a blue; value referred to the lightness or darkness of the colour; and chroma concerned the strength of the colour, as, for example, the difference between a red, weather-worn brick and the vermilion of a fire-wagon. A method of measuring colour on a solid sphere, irregular solid, and vertical and horizontal slices through the solid was described and a method of notation suggested. F. W. H.

VI.—Illumination and Illuminating Ware.

360. Sealing Wires into Electric Lamp Bulbs and Vacuum Tubes. NAAMLOOZE VENNOOHSCHAP PHILIPS' GLOEILAMPEN-FABRIEKEN, Eindhoven, Holland (Brit. Pat., No. **198322**, October 25th, 1922).—In electric lamps and vacuum tubes wherein leading-in wires, 3, 4, for heavy currents are attached to discs, 2, sealed within tubular extensions, 1, of the glass containers, the discs are made of chromium–iron alloy having a coefficient of expansion approximating to that of the glass. The parts of the conductors near the disc are preferably of nickel. H. G. C.
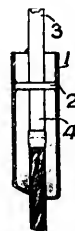
FIG. 161.

VII.—Fuels, Refractories, and Furnaces.

361. The Combustion of Gaseous Fuels. G. F. MOULTON (*J. Ind. Eng. Chem.*, 1923, **15**, 583).—Tests carried out using domestic range burners showed that as the ratio of primary air to gas was increased, the flame height decreased, and up to a certain air–gas ratio, the length of the inner cone decreased, but beyond this value the cone increased in length. As the proportion of air reached that necessary to burn the gas completely, the velocity of combustion increased less rapidly than for lower proportions, and the cone lengthened.

A comparison of flame and cone heights for 400, 500, and 600 B.T.U. water gas showed that, in a typical range burner, the difference in flame height was a little greater than the difference in cone height, but not so great as to be noticed. The difference was not of a magnitude to indicate any marked differences in utilisation efficiency of the gases.

A gas of greater specific gravity possessed a greater injecting power for primary air. A change in pressure without change in the orifice resulted in an air–gas ratio that was almost constant over the usual distribution pressures (from 2 to 6 inches).

Good flame contact was essential for high efficiency. Analysis of the products of combustion for carbon monoxide was undertaken, using the iodine pentoxide method with Larson and White's form of apparatus. Water gases of 500 and 600 B.T.U. per cu. ft. were consumed in a star burner under the best conditions of adjustment for each gas. The completeness of combustion was equal for the gases of different heating values. When an appliance was supplied with the same number of B.T.U. per hour, practically the same service was secured with the 500 and the 600 B.T.U. gases.

V. D.

362. Continuous Coal Control in Large Modern Boilers. R. Chansel (*Chal. Ind.*, 1923, **4**, 541).—Automatic, or semi-automatic weighing machines were costly in upkeep, and the necessary arbitrary corrections used rendered them useless for serious and continuous control.

A volume recorder, if enclosed in a stout box, was not readily put out of order, and the upkeep was negligible. The original cost was high, but was soon repaid in use.

Bailey's volume counter gave good results in general practice, but its sensibility was seriously reduced when the rate of consumption of the coal slackened. The length of tube, diameter, and position of the fuel column influenced the working of the vanes, and needed careful adjustment.

The Lea coal meter proved to be very satisfactory. The variation in size of grain did not affect its readings to any serious extent in practice. A scale enabled the depth of fire to be read. It could be attached to any type of feeder, and even in the case of hand-charging it could be employed in measuring the piles of coal deposited for each furnace or boiler, thereby eliminating errors due to weighing in trucks. The errors arising from the use of these volume-counting machines did not exceed 5 per cent., but were often of the order of 2 to 3 per cent. Details of results obtained on a Babcock-Wilcox boiler were given.

V. D.

363. Substituting Fuel Oil for Producer Gas in a Continuous Glass Tank. F. S. Thompson (*J. Amer. Cer. Soc.*, 1923, **6**,).—Three arrangements of burners were tried in a regenerative tank furnace designed normally for producer gas firing :

(1) Two end burners placed well above the level of the dog house and giving a flame which was also well above the level at which the air entered the furnace from the regenerators. This mode of operation appeared to bring the melting end and working end down to a fairly uniform temperature, so that either the working end was too hot or the melting end too cold.

(2) Two additional burners were placed in the side wall just over the bridge so as to fire across the tank at an angle of 45° to the

wall. The height of the burners was the same as that of the two end burners, and the result was that the side burner checked the flame from the end burner, thereby keeping it from the working end and raising the temperature of the melting end.

(3) The end burners were tried at a lower level without the side burners, so that the flame shot across the lines of exit of the air from the air ports.

This third position was found the best and simplest.

The following daily balance sheet was drawn up to compare the cost of coal and oil firing and appeared to be slightly in favour of the oil with the particular fuel prices mentioned.

	$
Producer power ⎫	
Coal crusher power ⎪	
Coal elevator power ⎬	2·20
Coal scale ⎭	
Producer men	15·12
Coal man	4·40
Removing ashes	1·10
Average daily consumption of coal (13·5 tons) in producer.. ..	94·50
Cost of steam	28·80
Burning out mains (one-seventh of cost)	2·00
Producer repairs	1·00
Interest on investment and depreciation	7·00
Total .. .. $156·12

The daily cost of operation with oil :—

	$
Cost of average daily consumption of fuel oil (2167 gal. at 4·5 cents)	97·52
Cost of delivery to burners	22·00
Cost of delivering air at 60 lb. pressure to burners	8·00
Repairs and upkeep on air compressor, oil pump, and pipe lines ..	3·00
Interest on investment in compressor, oil pump, and pipe lines ..	0·50
Depreciation on pumps and lines	0·50
Labour (three men 8 hours each)	13·20
Total .. .. $144·72

S. R. Scholes, referring to this record, stated that he had tried the oil fuel at the Federal Glass Co., Columbus, but as they paid rather more for oil and less for coal than in the figures recorded above, the economy was on the side of coal. Here again rear burners were employed and the temperatures obtained were good.

The burners were made by the W. N. Best Co., New York; the tank furnace supplied glass to Westlake machines.   W. E. S. T.

364. The Concentration and Purification of Gas Constituents of Gaseous Mixtures by Means of Materials with Large Surface Areas. E. BERL and O. SCHMIDT (*Zeitsch. angew. Chem.*, 1923, **36**, 247).—By means of bodies such as "active carbon," colloidal kieselguhr, colloidal ferric hydroxide, zeolite, etc., it was known to be possible to separate individual constituents from gaseous mixtures, in a manner which could be said to be similar to the fractional distillation of liquids. An apparatus for the quantitative separation of producer gas was described, and curves were given for the experiments carried out.   W. C. S.

365. The Mechanical Properties of Refractory Materials at High Temperatures. E. L. DUPUY (*Rev. Met.*, 1922, **19**, 672).— The resistance to crushing of silicious or aluminous substances diminished somewhat with rise of temperature at first, then rapidly increased to a maximum at about 1000°, sometimes reaching double, or even treble, the value at atmospheric temperature. At still higher temperatures the strength diminished rapidly until complete fusion occurred.   Ferrochrome and magnesia products did not show this maximum strength On cooling, after the maximum point had been reached, the materials regained a certain solidity, and it was obvious that part of the material had been in a more or less plastic state.   The more easily fusible constituents of the mass had formed a more or less viscous fluid, offering increased resistance to deformation or crushing, when the load was applied rapidly.   The rate at which the load was applied was the important factor on which the mechanical properties depended at high temperatures.   When softening was taking place, the resistance to crushing was far greater than for the cold material, when the load was applied very rapidly, but decreasing the speed of application of the load produced a distinct fall in the strength of the material. A static or constant load showed no maximum in the strength of the material, gradual deformation of the specimen taking place. This condition most nearly resembled the conditions met with in works practice.

In the absence of impurities which would form a liquid phase on heating, as is the case with pure oxides or silicates, the resistance to crushing did not exhibit a maximum value.

A certain felspathic kaolin showed two maxima, the second at a temperature of about 1,400°, but this also disappeared under a slow test, or when the bricks were treated to a preliminary heating to 1500—1550°, and then cooled slowly.   The measurements were made, using an apparatus similar to that of H. Le Chatelier and B. Bogitch.   V. D.

366. The Disintegration of Refractory Bricks by Carbon Monoxide. B. M. O'HARRA and W. J. DARBY (*J. Amer. Cer. Soc.*, 1923, **6**, 904).—Tests were made on various kinds of bricks of the effects of pure carbon monoxide at various temperatures. Firebricks containing many particles of iron oxide were broken up by the increase in volume produced by the deposition of carbon at "iron spots" due to the catalysis by iron of the reaction :

$$2CO = CO_2 + C.$$
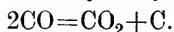
The action of carbon monoxide was not great at moderately high temperatures (not important above 750° or 800°), but increased rapidly as the temperature approached 550°.   Firebricks with low iron content withstood the action of carbon monoxide for a much longer time than firebricks of high iron content.

A magnesite brick (Fe_2O_3, 5·02 per cent.; SiO_2, 6·43 per cent.; MgO, 84·7 per cent.) was badly attacked at 550°, half of it having fallen completely to powder after fifty-three hours, and the remainder

being friable and easily pulverised between the fingers. Silica, carborundum, and chrome (low in free iron oxide) bricks were not affected. F. W. H.

367. Silica Cement. E. N. McGEE (*J. Amer. Cer. Soc.*, 1923, **6**, 896).—Silica cement was usually manufactured from ground silica bricks with sufficient plastic clay to give a proper plasticity and bonding power. The plastic clay should be refractory, fairly high in silica content, and be used in just sufficient quantity to produce the desired results; the quantity required was usually about 25 per cent. Some manufacturers used a mixture of silica brick, 50 per cent., ganister rock, 25 per cent., plastic clay, 25 per cent.

The effect of the percentages of plastic clay (fusion point, Orton cone, 27, 1,610°), on the fusion point of a silica cement was illustrated by the following figures :

Ground Silica Brick. Per cent.	Plastic Clay. Per cent.	Fusion point.		
100	0	Orton cone 31 +		
90	10	..	,,	31 −
80	20	,,	,,	30
75	25	,,	,,	29
70	30	,,	,,	28
65	35	,,	,,	27—28
60	40	,,	,,	26—27

The use of raw ganister rock appeared to increase the refractoriness of the cement, as indicated by the following data :

Plastic Clay. Per cent.	Ground Silica Brick. Per cent.	Raw Ganister. Per cent.	Fusion Point.		
25	75	0	Orton cone 26—27		
25	50	25	,,	,,	28
25	37·5	37·5	,,	,,	30
25	0	75	,,	,,	31½

The cement should be of a fine grain. The specifications of the Semet-Solvay Company required that the cement should be of such fineness that approximately all would pass a 30-mesh screen (Bureau of Standards). The following were actual sifting tests on various silica cements, as received :

					Silica Cements.					
					(1).	(2).	(3).	(4).	(5).	(6).
Percentage through 30-mesh screen					99·4	99·5	99·0	99·7	99·8	100
,,	,,	40-	,,	,,	96·8	97·5	93·6	99·5	94·5	99·6
,,	,,	60-	,,	,,	75·8	69·9	68·4	90·7	66·1	80·6
,,	,,	80-	,,	,,	65·0	59·9	56·5	82·0	54·9	71·6
,,	..	100-	,,	,,	58·7	54·0	49·3	71·3	47·1	62·0
,,	,,	200-	,,	,,	44·0	39·8	35·7	48·1	28·7	36·7
Fusion point in Orton cones					28—29	28—29	30	20—26	29	29

If fusion point and fineness were satisfactory, it was only necessary to know whether the cement had satisfactory working and bonding qualities. To test the first, the cement was mixed

with water to the consistency of dipping mortar and allowed to stand eighteen hours. If it had not then settled so as to cake the bottom of the pail, experience showed that it would spread smoothly and easily. For bonding qualities, a simple test was to butter the cement between the flat surfaces of two 9-inch, straight bricks and allow the joint to air-dry thoroughly. The cement should then support the lower brick when the upper brick was suspended with the joint in a horizontal plane.

An investigation showed that the introduction of a certain amount of molasses into the water used for mixing the cement greatly improved the bonding qualities without affecting the refractoriness.   F. W. H.

368. Notes on Burning Refractories, with Special Reference to the Control of Labour Costs. L. C. HEWITT (*Bull. Amer. Cer. Soc.*, 1923, **2**, 109).—It was often possible to obtain greatly increased efficiency from an existing equipment through slight changes in design methods of firing. For example, the goods should already be dry when set for firing. Regular inspection of underground flues and ducts was necessary in order to maintain full draught. The stack flue should be of adequate size to accommodate the kiln bottom flues which fed it, too large rather than too small.

The burning schedule should be controlled by the pyrometer and based on the vitrification, shrinkage, and porosity curves of the particular fire clay. Finally, detailed records of every firing should be kept for reference. The author also advocated payment to workmen of bonuses for success in maintaining correct standards of firing.   F. W. H.

369. Further Studies on Cast Glass Pots. R. F. GELLER and A. N. FINN (*J. Amer. Cer. Soc.*, 1923, **6**, 865).—A progress report covering the work done by the Bureau of Standards during the past three years.

The body compositions were given and contained 32, 50, or 52·5 per cent. of grog. The grog used was a mixture of 10—20-mesh, 20—40-mesh, and less than 40-mesh sizes in the following respective percentage proportions, 35, 45, 20, and 20, 50, 30.

The deflocculating agent generally used consisted of sodium carbonate, 0 to 80 parts per 100 parts of sodium silicate, whilst excellent casts were obtained by means of sodium carbonate, gallic acid and sodium silicate in the ratios, 8 : 8 : 100. The total amount of deflocculating agent used varied from 0·15 to 0·21 per cent. of the dry weight of the batch, depending on the percentage of plastic material in the body. The deflocculating agent was added to the water in the blunger before the clay was introduced and, after thoroughly blunging the entire batch, the quality of the slip was judged by its feel, and finally checked by a determination of its specific gravity.

The blunging usually occupied seven hours; the slip was then cast, the core removed after a further sixteen and a half hours,

and the outer shell twenty-four to thirty hours later. The pot was then "slicked" or smoothed over and carefully dried.

The pot was placed on three brick piers in the pot arch to permit a free circulation of furnace gases around it. The heating schedule used was as follows :

```
12 hours at  75°.
12   ,,      100°.
 3 hours to rise from 100° to 150°; maintained 9 hours.
 3   ,,      ,,      150° to 200°;      ,,    9  ,,
 3   ,,      ,,      200° to 250°;      ,,    9  ,,
 3   ,,      ,,      250° to 300°;      ,,    9  ,,
35   ,,      ,,      300° to 825° (15° per hour).
24   ,,      ,,      825° to 1,425° (25° per hour).
 8 hours at 1,425°.
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The temperature of the pot arch was measured by means of a thermo-couple projecting six inches through the crown and protected by a sillimanite tube.

Approximately one hundred pots had been cast and no failures had occurred except those resulting from the use of a mould too dry or a body of modified composition. A table was given showing a summary of observations on forty-four pots used in the manufacture of optical glass.

The effect of higher pot arch temperatures on the final porosity of the body was illustrated by the following figures :

Pot No.	Max. Temp. in Pot Arch.	Time held at Max. Temp.	Mean Porosity.
49	1,300°	8·5 hours	20·1
50	1,260	10·0 ,,	20·1
51	1,350	12·0 ,,	17·3
53	1,350	8·0 ,,	16·7
54	1,400	8·0 ,,	11·6
61	1,450	6·0 ,,	11·2
70	1,450	4·5 ,,	12·2
72	1,450	2·0 ,,	9·4

Firing the pots in the pot arch to 1000° and finishing in the furnace were not satisfactory, since the pot bottom was not thoroughly burned.

Four conclusions were drawn, (1) that the casting of porcelain pots had passed the experimental stage and had become a matter of plant routine requiring very little, if any, technical control; (2) that the ball clay and kaolin content was not a vital factor as long as the slip could be cast properly and form a body of dense and homogeneous structure; (3) that slow burning to about 300° practically eliminated fissures and surface cracks; and (4) that pots should be arched to the highest temperature consistent with the refractoriness of the body.   F. W. H.

370. Contribution to the Chemical Study of Several Kaolins and Clays. Anon. (*Sprechsaal*, 1923, **56**, 289, 301).—Seger's "clay substance" (that part of clay which is decomposed by concentrated sulphuric acid, and having an empirical formula $Al_2O_3,2SiO_2,2H_2O$) had been shown to consist of several groups

of compounds. I. M. van Bemmelen had divided clays into two portions :

A.—Silicate soluble, or decomposed by hydrochloric acid.

B.—A sort of kaolin silicate B, not affected by hydrochloric acid, but quite decomposed by hot concentrated sulphuric acid.

Other workers had used the method of distinguishing between these portions of the clay substance, but methods of analysis were varied and so differences had been obtained in the results. The materials should be prepared carefully, the grain size of the sample should not be greater than would pass a mesh 422 per cm.² ; and it should be stored in a stoppered bottle in a room of a steady temperature.

The temperature at which the clay substance was disintegrated had been the subject of discussion for a long time. Le Chatelier and Rieke had studied the heating curves and the moisture losses with heat. Mellor and Holdcroft, and also Sokoloff had found the most violent liberation of moisture between 500° and 600°. It had been found that clay after ignition to a red heat appeared to have different soluble properties from those it had previously held, and on this fact the following analytical method had been based for rational analysis :

A Rose crucible and lid were weighed inside a weighing bottle with ground-in stopper, until of constant weight. A known weight of clay (about 5 gm.) was placed in the crucible, ignited for four hours in an electric furnace at 710° within limits of ±10°, and weighed after cooling. This fired clay was kept in a stoppered bottle in a desiccator and further samples were weighed by difference, care being taken to preserve the contents of the bottle bone dry. The sample taken was placed in a 300 c.c. Erlenmeyer flask and 1 c.c. of 2N-HCl added per 0·01 gm. of sample, the flask closed with a one-holed rubber stopper in which was held a glass tube ½ m. long and kept on the water-bath for two hours so that the acid was at the same level as the water outside. Then the solution was filtered through a fine filter, the residue being washed into the flask on the water-bath with the same acid mixture, and filtered and washed again. This second boiling served to remove all soluble alumina. The second filtrate was evaporated and the silicic acid precipitated. The silicic acid was filtered and together with the silicic acid from the residue estimated gravimetrically. Alumina and iron were precipitated from the filtrate and weighed.

The portion insoluble in hydrochloric acid consisted of quartz, felspar, and amorphous silicic acid. This residue was treated three times in a beaker with sodium carbonate solution, and three times with water, the bulked liquids being neutralised with hydrochloric acid and evaporated, and the silica and alumina determined.

The estimation of the portion soluble in hydrochloric acid (as according to van Bemmelen) had been the subject of much discussion, but the following definite method of analysis was given : 3 gm. of air-dried substance were placed in a 200 c.c. beaker and covered with 60 c.c. of hydrochloric acid (sp. gr. 1·10), this acid

having been previously warmed on the water-bath for ten minutes. The beaker and contents were covered with a glass, and placed on a water-bath so that the beaker was standing in boiling water. The beaker was agitated and after one hour the boiling was stopped and the beaker filled with 200 c.c. of water, allowed to settle over-night, and decanted. The residue was treated with 600 c.c. of acid, as quoted, for an hour, and the remaining residue well washed (decanted two or three times, using common salt or an ammonium salt if necessary, to hasten the precipitation). The washing liquid, the decanted solution, the hydrochloric acid and solution were evaporated on the water-bath, and the silicic acid was abstracted. In the filtrate, the iron and alumina were precipitated and weighed.

A 200 c.c. beaker containing 60 c.c. $2N$-soda solution was placed in a deep 400 c.c. beaker partly filled with water pre-heated at 50° or 60°. The soda solution, when it had reached 50° was poured on the residue obtained from the action of the hydrochloric acid on the clay taken, and then after thorough digestion, was diluted with water, cooled, and decanted. The residue was extracted with 60 c.c. of soda solution and washed by decantation, the liquids being massed and the silicic acid estimated after neutralisation. The two silica estimations were then summed.

In a set of results obtained it was shown that, unless great care was taken, analyses would give variable results even from the same homogeneous sample. Thus, differences in rational analyses varied from 0·16 to 4·20 per cent. for kaolin, 0·16 to 3·67 for clay and 3·24 to 6·98 for felspar.

It was essential to use acid of a definite concentration, with uniform duration of heating, and steady temperature. When firing the clay before dissolving it in hydrochloric acid, the temperature of firing should lie between 730° and 750°.

Apparently there was a relation to be noticed, between the silica percentage in part A and the hygroscopic value of the clay :

Sample.	SiO$_2$ in part A. Per cent.	Hygr. Value. Per cent.	Sample.	SiO$_2$ in part A. Per cent.	Hygr. Value. Per cent.
K III	3·04	2·22	T III	8·71	6·71
K IV	4·14	3·66	T IV	6·29	6·32
T I	7·50	9·55	T V	7·63	8·28

This " part A," however, needed much more study, the ratio $SiO_2 : Al_2O_3$ being subject to much greater variations than that in part B, which more or less remained at the value 2 : 1. W. C. S.

371. A Preliminary Study of Zirkite Ore. J. G. THOMPSON (*J. Phys. Chem.*, 1922, **26**, 812).—*Zirkite*, an impure zirconium dioxide, obtained from large deposits of *baddeleyite* ore in Brazil, has been used successfully in the manufacture of combustion boats and tubes for high temperature work. The melting point lay between 1,200° and 2,000°, according to the composition, whilst that of pure zirconium dioxide was 2950—3000°. The success of the ore as a refractory material therefore depended on its purification, and the resulting rise in melting point.

The best method of decomposition of the ores used in the investigation was found to be by means of fusion with borax. Decomposition by fusion with alkalis was not applicable to ores, only to silicates and phosphates. Fusion with fluorides, or conversion to carbides was rejected on account of loss due to volatilisation. Alkali fusion followed by pyrosulphate fusion was successful but tedious.

The composition of the ore under investigation was represented by means of the ratio, on a metallic basis, of the elements present, as 100 Zr : 15·1 Si : 5·37 Fe : 0·89 Ti.

The chief impurities, silicon and iron, were to be removed if the ore were to be rendered highly refractory.

Attempts were made to eliminate the silicon as carbide, which compound was less stable at high temperatures than the zirconium carbide. Experiments carried out with a resistance furnace were unsatisfactory; but when an arc furnace was used, and a mixture of ore and petroleum coke was heated strongly, a maximum removal of silica was obtained when the ratio of ore to carbon was 100 : 15, that is, when the amount of carbon was a little in excess of that required to transform only the silicon to carbide. This treatment removed 90—95 per cent. of the silicon in the zirkite. If excess carbon were used, the removal of silicon was less complete, owing, probably, to the formation of stable double carbides of silicon and zirconium, or of solutions of silicon carbide in solid zirconium carbide. Zirconium carbide had a very high melting point, being infusible in a 40—50 kw. arc, and was very stable in a reducing atmosphere, but if it were to be employed as a refractory material it would need to be protected from oxidation, as it readily oxidised at high temperatures.

Very little iron was removed in the arc furnace treatment, and this had to be removed later by treatment of the carbides or oxides with chlorine or phosgene.

The full treatment promised to give a purified zirconia, which would be valuable as a refractory substance.   V. D.

372. Refractory Abrasive Compositions. L. E. BOURDEAU, 21, Rue Jeanne Hachette, Ivry, Seine, France (Brit. Pat., No. **200903**, April 19th, 1922).—An abrasive refractory composition is made by fusing a mixture consisting chiefly of bauxite and basalt, with smaller proportions of ilmenite, cerite, carbon, and a flux, such as sodium fluosilicate. Substances such as emery, corundum, flint, and quartz may also be added. The product may be coloured by the addition of suitable oxides so as to indicate its degree of hardness.   H. G. C.

373. Heat Economy in the Glass Industry. (*Sprechsaal*, 1923, **56**, 134, 146, 165, 177, 274, 283, 292, 303.—See also Abs. 276, p. 200).—*Case* 6.—A sheet-glass factory with one 6- and one 8-pot furnace was run by one revolving grate producer with a Körting injector, burning a mixture of briquettes and Bohemian lignite, whilst a second similar producer was held in reserve.

Analysis of the gas gave the percentage composition as CO_2, 15·6; CO, 16·6; H_2, 28·4, with a large moisture content, and a heat value of only 1460 Cal. per cub. m.   After throttling the blast to 60 mm. pressure (water gauge), the composition of the gas was improved to CO_2, 6·2; CO, 28·3; H_2, 19·2, with a heat value of 1700 Cal. per cub. m.   It was considered advantageous, however, to put both producers into use, each then having a smaller load.   By this means pressure variations during ash removal were minimised, and clinkering was reduced.   For better control, a pressure-gauge was placed in the air inlet and a thermometer in the air–steam mixture, both of these recording on the producer platform for the benefit of the producer-man.   The steam–air pipe was insulated to prevent condensation losses, a further move in the same direction being the use of warm air taken from the neighbourhood of the regenerators or the glass pocket.   Eventually a pre-heater for the blast air was built into the waste-gas flue, and the air obtained at a temperature of 70°.   Analysis of the waste-gas from the furnace gave a percentage value of CO_2, 16·7; O_2, 0·3; CO, 3·0, with small amounts of CH_4 and H_2.   This indicated that only three-quarters of the gas was being burnt in the furnace, due to lack of sufficient secondary air.   To obviate this, a recorder was installed to indicate the amount of CO_2 and unburnt gases in the waste gas, whereby continuous regulation of the secondary air could be accomplished. Finally, the lack of temperature control in the flattening oven was found to result in too great a softening of the cylinders in the delivery tube, with a consequently large breakage loss, and a sulphuring of the glass in the muffle itself.   The latter defect, which took place at a yellow glow, was found to be obviated at a red heat.

Case 7.—The chimney of a sheet-glass tank gave a rather dense smoke, and more so at periods of reversal than at other times.   A faulty gas-reversal valve, which allowed good gas to pass into the waste-gas flue and there partly burn, was found to be the cause of the trouble.   The method of detection consisted in using a fully oxidised mixture in the furnace, whereby waste gas from the regenerators contained no combustible ingredients.   Analysis of the gas before and after passing the valve then served to localise the leak.

Case 9.—In a study of the efficiency of a sheet-glass factory in which the waste gases from three flattening ovens and lehrs passed into a flue lying below the lehr and then into a common chimney, the possibility of generating steam for the producer by means of the flue gas was investigated.   These ovens had a coal consumption of 7500 kg. per twenty-four hours, the moist coal containing 5·5 per cent. of ash, 6·5 per cent. of moisture, and 70·4 per cent. of carbon. Assuming a 5 per cent. loss of carbon in the ash and as soot, each kg. of coal produced $0·704 \times 0·95 = 0·67$ kg. of carbon in the waste gas, which had a percentage composition of CO_2, 8·3; O_2, 12·1; N_2, 79·6.   Each cub. m. of CO_2 contained 0·536 kg. of carbon, so that 1 cub. m. of waste gas contained $0·083 \times 0·536 = 0·0445$ kg. of carbon, and 1 kg. of coal produced $0·670 \times 0·0445 = 15$ cub. m.

(approx.) of waste gas. The production of flue gas per twenty-four hours was $7,500 \times 15 = 112,500$ cub. m., with a temperature of about $600°$. This gas would enter an ordinary waste-gas boiler at $550°$ and emerge at $350°$, although specially designed boilers would reduce the temperature of emission to 250—$150°$. The gas had a specific heat (per 1 cub. m. per degree) of 0.34, and with an efficiency of 80 per cent. the heat given up per twenty-four hours was $0.80 \times 112,500 \times 0.34 \times 200 = 6,120,000$ Cal. To raise 1 kg. of water at $20°$ to steam at 5 atmos. ($158°$), 637 Cal. were required, so that the steam production per day would be $6,120,000 \div 637 = 9600$ kg. A gas analysis at the producer revealed a consumption of 0.35 to 0.4 kg. of steam per kg. of coal used, so that a producer consuming 15,000 kg. of coal would require 5,000 to 6,000 kg. of steam per day, and such a producer could be supplied by the ovens if no undue heat losses occurred.

Case 11.—A producer, firing a mixture of 3500 kg. of briquettes with a moisture content of 20 per cent., and 7500 kg. of lignite with 60 per cent. of moisture per day, gave a very moist gas which it was desired to dry partly. Drying was accomplished by cooling the gas, in order to reduce its saturation value. Direct water cooling by jets was impossible, because of the difficulty of separating condensed tar from the large volume of water used, and an indirect method, in which the gas passed through a large number of narrow tubes, surrounded by a current of cooling water, was employed. The condensed tar was easily separated from the small volume of condensate, and the water was then mixed with the larger volume of cooling water, which was at a temperature of $45°$ to $55°$. By such means tar in solution in the condensed liquid was prevented from solidifying (a process which only occurred at $30°$), and no stoppage of pipes took place. It was often found worth while to separate the " low-temperature tar " obtained at 300—$450°$ from lignite-burning producers, for this tar at $500°$ was decomposed into ordinary tar and volatile hydrocarbons. In cases in which the lignite contained more than 20—25 per cent. of moisture, the tar obtained was of inferior value, and, as a remedy, a previous drying of the fuel was necessary.

Case 13.—A factory with revolving-bottom producers had much difficulty due to clinkering. Causes of the trouble were : (1) The fuel, chiefly coal, was of very irregular grading and with only 20—30 per cent. of large size material; (2) transport on to the producer platform, accomplished by means of a grab bucket, introduced at least 10 per cent. of sand and gravel; (3) glass cullet, lumps of clay, and potsherds found their way in fairly considerable amounts on to the platform and into the fuel; (4) irregular blast conditions allowed varying proportions of steam and air to enter the grate.   A. C.

374. Methods of Firing Control in the Ceramic Industry. A. GRANGER (*Chal. Ind.*, 1923, **4**, 527).—A chronological account of the development of methods of heating control in the ceramic industries.

For successful work, the time–temperature relation, as well as the actual temperature and the conditions of the atmosphere must be studied carefully. It was necessary, however, to maintain the same chemical composition in the " test " as in the wares themselves, as a slight chemical change often resulted in entirely different pyrometric properties. It was difficult to compare results on this account. The *rôles* of pyrometers and of " test-pieces " were entirely different, and the one could not successfully replace the other. Tests pieces gave easy control, and the changes observed in them were indicative of those taking place in the wares, but they gave no indication of fluctuations in temperature, and the indications were non-continuous. Pyrometers, on the other hand, gave continuous records, but they were much more complicated in use and interpretation, and, moreover, they were liable to serious errors.   V. D.

375. Difficulties met with in Using a Works Pyrometer Installation. R. S. WHIPPLE (*Le Verre*, 1922, **2**, 25 and 49).— Sources of trouble in the use of pyrometers in works were (*a*) choice of an unsuitable type of instrument, (*b*) incorrect fixing and use, and (*c*) lack of calibration and correction.

Choice of instrument should be influenced by the range of temperature, degree of precision required, and whether indications or records of temperatures were necessary. The best arrangement for reading, so that the workmen and manager could follow the temperature changes, was to put a recorder in the office, and an indicator near the furnace, coupled to the pyrometer in parallel.

Resistance thermometers were most useful over a range of 200° to 700°, whilst thermo-couples served best for temperatures of 0° to 1,200°, and optical or radiation pyrometers were to be chosen for a range of 700—2000° or more. The instrument selected should be capable of an accuracy of 0·1 per cent. or of 1° in 1000°.

The protective sheath of a thermo-couple should be mechanically strong, and resistant to heat. Any breakage should be at once reported, as its function was essential.

Galvanometer and indicator supports were to be placed so as to be as free as possible from vibration. Dust, and fumes were to be excluded from the recording part of the installation, and defective junctions in the circuit were to be avoided. Galvanometers and recorders were to be protected from any superheating and mechanical abuse.

The indicators or recorders should be standardised and calibrated by trustworthy technical workers, and checked periodically against a specially protected standard.

Thermo-couples, even when calibrated correctly, suffered from errors due to (1) gradual change of the electromotive force of the couple, (2) unknown temperature of cold junction, (3) resistance of defective connections, and (4) change of temperature in the galvanometer or indicator. Of these, any uncertainty of the temperature of the cold junction was the most serious, and called for special control. An oil-bath remained constant in temperature more than

twenty-four hours, whilst a junction placed some distance below ground level remained constant for more than a year.

The galvanometer zero called for correction at any temperature except that at which it was calibrated.   The type of galvanometer must be chosen so as to suit the thermo-couple, in order to maintain, as nearly as possible, a constant resistance in the circuit.   In order to avoid heating, the galvanometer was to be put at a distance, using compensating leads.   The more accurate method of measuring the electro-motive force of a thermo-couple by means of a potentio-meter, was advocated for great precision, although the readings were not direct or continuous.

Resistance pyrometers required similar control, and needed careful, frequent checking.

When optical or radiation pyrometers were in use, the condition of the furnace approximated to those of a perfect black body, or the temperature was read too low.   If used correctly and with care, very little difference was observed between the temperatures registered by a thermo-electric, and a radiation pyrometer, although care was very necessary.   In practice, when repetition of definite conditions was more essential than registration of actual true temperature, these radiation instruments were of great value.   They could be operated at a distance from the furnace, and could be permanently installed.   No personal equation of an operator crept in to disturb the records.

Any tube inserted in the furnace, for use with a Féry recording pyrometer must not cut off any of the radiation.   The mirror in the instrument must be kept clean and bright.   Unoxidisable steel mirrors were considered the most satisfactory.

In the use of a disappearing filament pyrometer it was important that the lenses were true, and that the lamp was in good working condition.

The adjustment and choice of the ground glass screen placed before the amyl acetate lamp in a spectro-photometer pyrometer was important, in order to produce a uniform field.

Radiation pyrometers should be checked against a thermo-couple, using an electric tube furnace or gas muffle, at a temperature of 1,200—1,400°.   The thermo-couple should be placed in the front part of the furnace, and the readings of the two instruments should be carefully compared.

Any form of pyrometric installation called for individual and exceedingly careful supervision and control, if it were to be trust-worthy and helpful.   V. D.

376. Disappearance of the Filament and Diffraction Effects in Improved Forms of an Optical Pyrometer. C. O. FAIRCHILD and W. H. HOOVER.   (*J. Optical Soc. Amer.*, 1923, **7**, 543).—The disappearing filament optical pyrometer consisted of a telescope or microscope in the focal plane of which was placed an electric lamp with a small filament.   The temperature of a glowing object was measured by matching the brightness of the filament with that of the image of the object, projected in the plane of the filament.

The precision attainable depended on the perfect disappearance of the filament when the current through it was adjusted until the brightness of the image and filament was apparently the same.   Non-disappearance of the filament was caused by diffraction, and if the filament was a wire, by reflection at its edges.   The authors made a detailed investigation of the diffraction problem and found the conditions for perfect disappearance of the two types of filament. The flat form was particularly useful in making exact measurements and in measuring lower temperatures, that is, down to 630°.

A laboratory form of pyrometer, embodying the results of the investigation, was described in detail, as also the principle of two special forms of micropyrometer.

<div align="right">J. R. C.</div>

377. Temperature Control in Glass Furnaces. Communicated by Consulting Bureau for Heat Technology, of the German Glass Industry (*Sprechsaal*, 1923, **56**, 102).—A plea for the use of instruments of control on glass furnaces.

Temperature measurements should be made at several points as follows : (1) The steam blast into the producer so as to control the amount of moisture entering.   (2) The flue leading from the producer, since each fluctuation of temperature of the producer gas only served to vary the temperature of the regenerators with harmful results.   (3) The air in the air port of the burners at each side, in order to ascertain whether pre-heating was insufficient or excessive, and likely to lead to trouble with the crown of the furnace, or an undue shortening of the flame with consequent corrosion of the ports.   A specimen chart showed how these temperature curves followed a wave motion due to changing over and the alternation of heating and cooling; at the same time, a definite " peak " was not to be seen when the thermo-element was sheathed. Nevertheless, the curves acted as a check on the periods of changing-over and indicated whether one side of the furnace was working hotter than the other, as might be the case after intermittent repairs or due to leakage.   (4) Both the melting end and working end of the tank, but the thermo-elements should be built in very carefully and well sheathed.   On no account should the metals come in contact with a flame, and flame temperatures should be taken with a radiation pyrometer.   Readings in this region were known as the " furnace temperature," because local conditions altered the readings appreciably with different instruments, sheaths, and arrangements; in general, however, between 1,300° and 1,400° was obtained at the melting end, and between 1,150° and 1,200° at the working end.   The curve obtained from the recorder at the melting end should be as high as possible, but that obtained at the working end as steady as possible.   (5) The flue leading to the chimney stack.   An excessive temperature implied loss of heat. Generally, from 450° to 300° was satisfactory, and any excess might be due to lack of regeneration or blockage, whilst too low a temperature would lead to inefficient regeneration later.   If such a state of affairs were to occur, the generation of more gas might

rectify it, provided that secondary air also could be supplied, as indeed it might be, through leaks in the furnace.

Beyond the systematic measurements outlined it would be advisable to take occasional measurements in each producer, at different points in the gas mains, at various heights in the gas and air regenerators, the furnace, and in the waste flue.   For an effective check, it was essential to analyse the fuel gas and waste gas, so that the working of the producer and the efficiency of combustion in the furnace could be visualised; furthermore, the moisture in the gas, its draught and pressure were required to obtain the end in view, namely, fuel economy.   In one factory a coal economy of 10 per cent. was effected, and only 2 per cent. of this amount had to be returned as cost of extra supervision.   W. C. S.

378. Precautions to be Taken in Order to Avoid Errors in the Measurement of Temperature.   O. KNOBLAUCH (*Chal. Ind.*, 1923, **4**, 439, and *Archiv für Warmewirtschaft*).—Thermoelectric couples or resistance thermometers should be used for determining the temperature inside solids, the wires being placed tangentially to lines of uniform temperature, and not at right angles to them.

Measurements made on solid surfaces necessitated intimate contact with the surface, and might be accomplished by the use of a thin copper disc attached to the wires, pressed firmly on to a considerable area of the surface at a uniform temperature; the wires also lay along the surface.

The temperatures of liquids could be measured by means of liquid, resistance, or thermo-electric thermometers, care being taken to pack any protecting thin jackets with a good conductor such as copper dust or oil.

When measuring gas temperatures, it was necessary to insert the thermometer as far as possible into the gas, to reduce the thickness of any jacket, to place the instrument across the direction of flow of the gas, and to insulate carefully or to heat externally all the containing vessel, especially at the place where the thermometer was inserted.   V. D.

379. Electric Glass Melting Furnace.   A. GRAUEL, Oshawa, Ontario, Canada (Brit. Pat., No. **200900**, April 19th, 1922).—In glass refining furnaces of the type comprising a number of interconnected
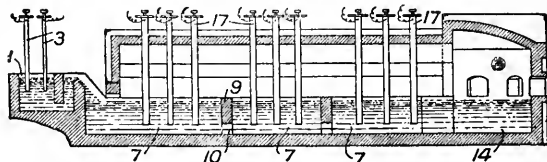
FIG. 162.

chambers, 7, provided with electrodes, 17, the chambers are separated by partition walls, 9, having openings, 10, at the bottom thereof through which the glass flows from one chamber to the other.   A melting pot, 1, provided with electrodes, 3, and a work chamber, 14, are arranged at opposite ends of the furnace.   H. G. C.

380. Recuperation and Heat Recovery. E. R. Posnack (*Glass Industry*, 1923, **4**, 167 and 188).—A general outline of the advantages of recuperation was given, reference being made to the
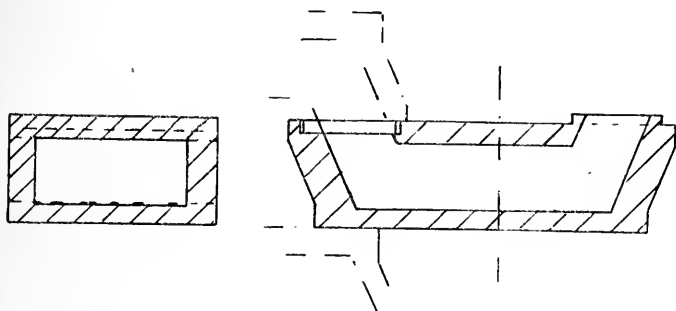
Fig. 163.

lower labour costs and the avoidance of extremes of temperature, which were both to be found in regeneration practice. The author had designed a tile (Fig. 163) by the use of which he claimed the requirements of recuperators were satisfied.   W. C. S.

381. A Regenerative Glass Tank Furnace. S. Crosbie, Whetstone, Middlesex (Brit. Pat., No. **201386**, March 16th, 1923).—Glass furnaces; regenerators.

A liquid or gaseous fuel furnace suitable for use in connection with glass-melting tanks is provided, as shown in Fig. 164, with air-heating chambers, 13, at the sides of the furnace through which pass the combustion products from the melting-tank, 1. Each chamber is provided with damper-controlled inlets, 14, for combustion products and one or more outlets, 15. Air to be heated is sup-

Fig. 164.

plied by a fan through piping, 16, 17, arranged in the chambers, 13, and is led by extensions, 18, to the burners, 19, means being provided for controlling the air supply. The floor of the glass tank, 1, is arranged above a series of air ducts which tend to keep it cool.   H. G. C.
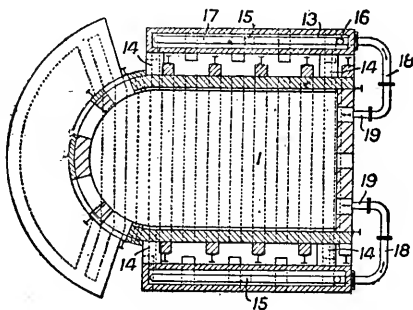
382. A Simple Gas Melting Furnace. J. Meyer and H. Bratke (*Chem. Zeitung*, 1923, **47**, 337).—Having found an electric furnace too sensitive, the authors constructed a cheap and simple furnace as follows : A heavy asbestos sheet of about 25 to 35 cm. diameter was pierced with a circular hole of 6 cm. diameter in the

centre, on which a Hessian crucible, *B*, of 6·5 cm. diameter was inverted, so as to leave an annular space of about 1·5 cm. when either a Bunsen, a Teclu, or even a Meker burner was placed underneath.
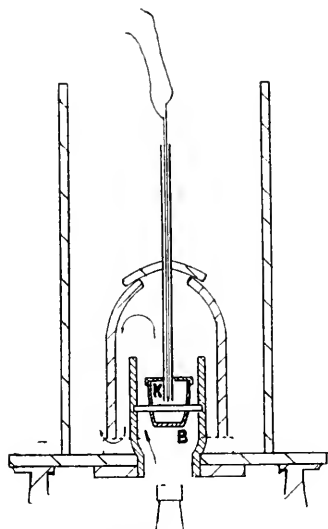
FIG. 165.

Another asbestos board was cemented below the first by means of a paste of 40 gm. clay, 40 gm. quartz sand, 4 gm. precipitated chalk, 2 gm. borax, and some firebrick dust with some concentrated water-glass solution. This was air-dried for a few hours, and then ignited by means of the Meker burner. The small clay hearth, *B*, contained the melting crucible supported on a fireclay triangle which had been cemented into three holes bored in the sides for this purpose. Three small asbestos discs were next cemented to the original board, to serve as feet on which a bigger dome 12 cm. diameter and 12 cm. high could stand. Finally a chimney was placed round the whole arrangement, having a height of 50 cm. and diameter 15 cm. The crucible, *K*, for the experiment was about 8 cm. high, and might be a porcelain or a Hessian crucible, the lid being of asbestos with the sides bent down. The lid of the outer chamber was covered with asbestos, but pierced so that a thermo-couple could be introduced. Observation was kept on the crucible by means of mirrors below the lower aperture, either above or below the burners. More than one burner might be used; the authors reached 860° in ten to fifteen minutes by means of a Bunsen, and 1030° by a Teclu, but with a Meker burner 1250° to 1300° was reached in fifteen minutes.   W. C. S.

383. Initial Heat Lehrs. W. S. MAYERS (*Glass Industry*, 1923, **4**, 163).—At the instant of leaving the mould, heavy glass articles contained sufficient heat to make them glow, but apparently the chilled skin caused them to retain their shape. A rapid transference of the article into a heated—and heat insulated—lehr arrested rapid cooling, so that only forty-five minutes were found necessary to effect good annealing, as against four and a half hours in the larger lehrs following older practice. Further, more uniform heating was ensured throughout the metal, and heavy strains were thus avoided.

In view of the greatly reduced period of time occupied in the lehr, the latter need only have a fifth of the pan area of the older lehrs, so that if 600 square feet of lehr area were required for a

machine producing 40 pieces per minute, a convenient size for an initial heat lehr would be 36 inches wide and 40 feet long.

Structural difficulties were greatly reduced in these lehrs, since no fire-box was required, but the walls at the receiving end needed to be well covered with good insulating material. A small burner was necessary, however, to ensure pre-heating of the moving metallic parts, and the size and arrangement of this burner, location and size of vents in the hot end, and thickness of the walls would control the desired heat gradations. The author favoured a two-inch refractory lining in the hot end covered with from four to six inches of silocel or nonpareil insulating walls with gradual reduction in thickness, and bound by structural steel work. The pan conveyor should be of the endless uniform speed sype, and the ware should be either transferred through a uniformly hot insulated carrying-in conveyer, or the lehr placed so that its hot end was within two or three feet of the take-out mould, the take-off mechanism being actually part of the lehr.

The first cost of such lehrs was very favourable as against other modern types; maintanence costs were low; and much space was saved.   W. C. S.

384. An Improved Muffle Lehr. C. L. SHARP, Lancaster, Ohio (U.S.A. Pat., No. **1447633**, March 6th, 1923. Filed October 20th, 1920, No. 418141).—A muffle lehr has a combustion chamber on each side and the hot gases are led through channels in opposite directions over the muffle chamber, thus securing a more even distribution of temperature in the muffle chamber.

Fig. 166 shows a cross section through the front end of the lehr
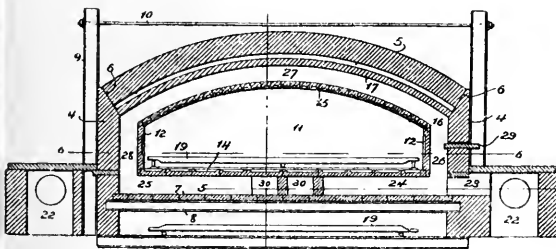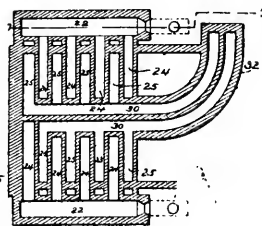
FIG. 166.   FIG. 167.

and Fig. 167 the arrangement in plan of the heating channels beneath the muffle chamber. The lehr is built up of side walls, and inner and outer crowns, 17, 5, respectively, the structure being braced by tie rods, 10. The muffle chamber, 11, is built up of tiles, 12, 14, 15, which are tongued and grooved into one another to prevent gas leakage, and they are supported by, and spaced from, the outer structure by other tiles, which form transverse gas channels 24, 25, 26, 27, 28. These channels afford communication between combustion chambers, 22, which are arranged on each side of the lehr, and flues, 30, arranged longitudinally beneath the floor of the

chamber and leading to the stack.   Each set of channels is connected to one or the other of the combustion chambers, 22, by a channel, 23, as shown in Fig. 166, so that the hot gases pass around the muffle chamber, 11, in opposite directions through alternate channels, and an even distribution of temperature is secured.   Dampers, 29, arranged in the channels, 26, enable the temperature to be regulated.   The floor channels may extend beyond the junction of the muffle chamber with the tunnel in order to prevent a sudden drop in the temperature of the ware as it travels out of the muffle chamber.   G. D.

385. An Electrically Heated Lehr.   I. H. FREESE, Clarksburg, West Virginia.   Assignor to the HAZEL ATLAS GLASS Co., Wheeling, West Virginia (U.S.A. Pat., December 19th, 1922, No. **1439305**. Filed January 17th, 1921, No. 437657).—This specification describes a portable, electrically heated lehr.   A series of sheet metal containers, mounted on an endless chain are covered with asbestos and wrapped with resistance wire.   Glass articles from the forming machine, while still hot are placed in the receivers, the lids of which are then closed.   Forward movement of the container then brings its roller contacts into engagement with fixed bars running down the side of the lehr.   This set of bars carries a 500 volt current, which is sufficient to keep the containers at the annealing temperature of the glass.   A second and third set of bars carry currents at decreasing voltages, giving progressively lower temperatures.
                                                                                        S. E.

386. Failure of a High Stack.   C. LOESER   (*Ker. Rundschau*, 1923, **31**, 189 and 199).—The article dealt with the failure of a stack designed to serve either one or two 16-chamber annular (Hofmann) chamber kilns for burning stoneware at a final temperature of 1,250°.   The only way to increase the maximum capacity for work of a given stack was to raise the temperature of the waste gases, since the cross-section of the outlet could not be increased. With low stack temperatures (100—120° in the case considered) and waste gases having a high water content, the ratio of the free internal cross-sectional area of the stack to the heat-absorbing and radiating surface, should be as large as possible.   The cross-sectional area increased as the square of the diameter, but the cooling surface only in direct proportion.   To increase the height of a stack above a certain limit would decrease and not increase its pulling power. This was due to the compulsory decrease of the internal diameter and of the thickness of the stack wall and to the extra cooling surface exposed.   In the case considered, the lengthening of a stack from 45 m. to 60 m., with a view to enable it to serve two kilns, caused a blackening of all the outer surface above a height of 35 m., and a decrease of pulling power, the stack barely sufficing for one kiln.   After demolition of the extra 15 m. of the stack, no blackening occurred, and the stack sufficed for the two kilns.   The author calculated that the shortening would have increased the cross-sectional area of the outlet from 0·78 sq. m. to 1·33 sq. m.

Blackening of stacks was caused by deposited tarry water penetrating the porous brickwork and especially through the binding material which it gradually corroded and destroyed.

Continuous chamber kilns tended to function unevenly, since at the full fire zone of 1,250°, for example, the gases occupied about five and a half times the volume they occupied at atmospheric temperature, and hence the gas velocities had to vary enormously from chamber to chamber, which were all of the same dimensions.

H. W. H.

387. The McGee Reversing Valve (*Glass Industry*, 1923, **4**, 200).—The valve was a self-contained six-way rotating valve, the producer gas preferably entered from overhead, the gas main coinciding with the common centre of the five outlets, which were all on the same level, two leading to the gas regenerators, two to the air regenerators, and one to the stack. Thus, normally, the gas tube was connected by a water seal to one regenerator, and
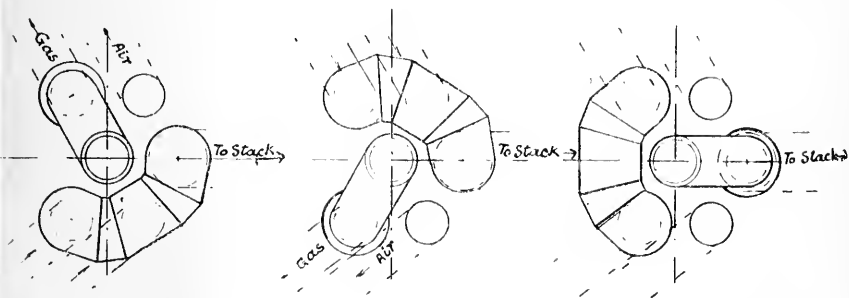
Fig. 168.

both the regenerators at the opposite end of the furnace were connected to the stack by the other tube. The air to the furnace was controlled by a damper, and the gas supply by a valve in the gas main. By interlocking, the gas flow could not be reversed until the regulating valve was closed, and after rotation, the six-way valve must be seated properly in its place before the gas regulating valve would open. The movements were accomplished by means of a small motor, and counterbalances, etc., were used to assist the movement. Means for burning out were provided, as well as for other operations.

W. C. S.

388. Glass Wool Heat Insulation in Europe. A. D. SABORSKY (*J. Amer. Cer. Soc.*, 1923, **6**, 674).—Glass wool had proved in practice, as well as in laboratory tests, to be the nearest approach to the perfect heat insulator.

It was made by melting scrap glass in vats or tanks having small openings in the bottom. From the openings, glass drops emerged, fell on to a rotating drum below, which carried them and the following threads of glass round the circumference, to form finally a substantial reel of wool. When the drum was full, the product

was cut off and then carded and loosened up by hand. The wool might be made into bands about three-eighths or half an inch in thickness and two to ten inches in width by sewing it on to paper, burlap or wire-mesh. For larger surfaces, requiring insulation, mattresses were made of the wool.

As a pipe insulator, glass wool found, perhaps, its best use. The author quoted one firm as stating that " in one of their tests with an eight inch, glass insulated pipe, carrying superheated steam at 630° F. and with a temperature of the surrounding air at 104° F., the drop in temperature per yard of pipe length was only 0·46° F. The surface temperature of the insulation remained only 9° F. higher than the surrounding air.

O. Knoblauch found the heat conductivity of glass wool per cubic metre per 1° C. surface difference per hour to be 0·030 calories at 0° C.; and 0·037 calories at 50°; 0·043 at 100°; 0·056 at 200°; 0·070 at 300°.

Generally speaking, glass-wool insulation, of about 20 per cent. less thickness, would replace the best grade asbestos insulations.

That glass wool was light was shown by the following figures :

Material.	Weight in lb. per cubic foot.
Asbestos–magnesia (loose mixture)	15·3 to 26·3
,, ,, (cast slabs)	17·7 to 24·0
Asbestos–kieselguhr (loose mixture)	34·3 to 41·7
Asbestos–kieselguhr–cork (loose mixture)	20·0 to 20·9
Kieselguhr (baked slab)	20·4
Glass wool (band form)	13·7

The portion of the insulation next hot surfaces might be melted and caked one-eighth to one-quarter of an inch in thickness, but behind the caked portion the insulation maintained its properties.

The first successful tests with glass wool were made in 1904 in Bohemia. Figures were given relating to the production of glass wool in Germany.   F. W. H.

389. The Relative Magnitude of Radiation and Convection Heating in a Muffle Kiln. J. T. LITTLETON, jun. (*J. Amer. Cer. Soc.*, 1923, **6**, 771).—The rates of heating by convection and by radiation in a Drakenfeld muffle kiln, 38 by 18 by 36 inches high were each determined for temperatures from 350° to 800° by means of a copper calorimeter placed in the muffle. Water from a tap was run through a quart thermos flask, then through the calorimeter and out through a second thermos flask. Sensitive thermometers in these flasks made it possible to determine the rise of temperature, and, from the rate of flow of the water, the actual heat received by the calorimeter. The furnace temperature was measured by means of six thermo-couples (iron–constantan) placed one couple at the centre of each wall. An average of the six thermo-couple readings was taken as the average wall temperature.

For the measurement of convection heating, the calorimeter was plated with gold and the reflecting power assumed to be 91

per cent. The radiation heating was measured by the same calorimeter covered with a mixture of platinum black and lamp black, having an assumed reflecting power of 4 per cent. The convection heating was expressed in the form of $C=\gamma(T-t)$, where C was the total converted energy per sq. cm. received by the body at the absolute temperature T from a surrounding gas at a temperature t, and γ was the constant applicable to the particular configuration. The convection constant γ was found to be $2 \cdot 34 \times 10^{-4}$ gram-calories per sq. cm. per second. The radiation heating, as measured, agreed with reasonable accuracy, with that computed by the Stefan-Boltzmann formula.

It was found that the ratio of convection to radiation heating decreased from about 0·4 at 350° to 0·1 at 800°, so that for higher temperatures the convection heating might be neglected in rough computations.   F. W. H.

VIII. Chemical Analysis.

390. The Analysis of Zirkite Ore. J. G. THOMPSON (*J. Phys. Chem.*, 1922, **26**, 812).—In the usual analytical separations the silica of the ore gave no trouble, but iron had to be removed before the zirconium could be estimated. Of many methods tried for this separation two were successful. These depended, respectively, on selective solubility of ferric chloride in ether, and the fact that iron, and not zirconium, was precipitated by H_2S from ammoniacal solutions containing tartaric acid. The ether method was to be preferred when large quantities of iron were present, but the precipitation method was necessary to remove the last traces of iron, and this method was directly applicable to the analysis of ores containing not more than 5 per cent. of iron oxide.

The most satisfactory method for the determination of zirconium and titanium was by precipitation with cupferron, the ammonium salt of nitrosophenylhydroxylamine.

In the modified method of analysis employed, silica, iron, titanium and zirconium alone were determined. The sample was ground to 80—100 mesh, then 0·5 gm. was fused in platinum with 5 gm. of borax, the fused mass, when clear, being distributed round the crucible sides. The melt was dissolved in 5 per cent. HCl. Ten to 15 c.c. of concentrated H_2SO_4 were added to the solution, which was evaporated until fuming strongly. The residue was cooled, diluted with water, and filtered. The silica was washed, and determined in the usual way; any slight residue of iron was taken up by pyrosulphate fusion and added to the main filtrate, which was diluted to 500 c.c. Ammonia was added, and the precipitate

coagulated by boiling; the clear liquid was decanted, then the precipitate was dissolved in 5—10 c.c. of concentrated H_2SO_4. One gram of tartaric acid was added, and the solution made ammoniacal, of bulk 150—200 c.c. H_2S was passed for twenty minutes, the solution was boiled for three to four minutes, cooled, and filtered. The precipitate was not washed. The filtrate was again treated with H_2S, the two precipitates of ferrous sulphide were dissolved in dilute aqua regia, and the iron was determined gravimetrically. Most of the H_2S was removed by boiling the filtrate, which was then made acid with a known excess of H_2SO_4, boiled again, and the sulphur filtered off. On cooling, the filtrate was diluted to 600 c.c., containing 7·5—10 per cent. free H_2SO_4. It was chilled in ice-water, and precipitated by a cold 6 per cent. aqueous solution of cupferron. The temperature had to be kept below 15°. After standing for half an hour, the precipitate was filtered under gentle suction and washed with cold 5 per cent. HCl. It was ignited and weighed as $ZrO_2 + TiO_2$. A pure white colour denoted ZrO_2 alone, whilst a yellow colour denoted the presence of TiO_2, and a red tinge indicated the presence of iron. The ignited oxides were fused with pyrosulphate, dissolved in 5 per cent. H_2SO_4, and the TiO_2 determined colorimetrically.   V. D.

IX.—Machinery for the Working of Glass.

391. Automatic Glass Bottle Manufacture. W. D. MORRISON, South Melbourne, Australia (Brit. Pat., No. **198485,** March 21st, 1922).—A glass-blowing machine comprises a number of moulds arranged in sets radially on a rotating table, a superposed feeding table intermittently rotated and provided with receiving pockets disposed radially in sets, and means fitted to the feeding table for delivering molten glass at predetermined times to receiving cups disposed in a radial casing which is adapted to deliver the charge of glass to the parison moulds.

The melting tank has a forehearth, 1, Fig. 169, which is provided on its underside with delivery orifices, 3, arranged in line. A table, 5, which is rotated intermittently, has receiving cups, 4, arranged in sets radially, so that a set registers with the orifices, 3, in the forehearth at each stoppage of the table, 5. Each set of the cups, 4, is carried by a sliding bar, 7, and as the cups are filled with the molten glass, the bar is moved outwards by an air cylinder, 9, thus shearing off the contained charges and closing the outlets of the orifices, 3. After the shearing, the table is rotated one step and the cups, 10, which close the bottoms of the cups, 4, are opened

to discharge the charges of glass into intermediate receiving cups,
12. The table, 5, can be adjusted vertically in order to bring it
close against the underside of the forehearth. . Passages, 6, through
which water circulates, are arranged around the orifices, 3, in the
forehearth to regulate their temperature. The receiving cups, 12,
are formed in a casing, 59, which swings about the central column,
2, of the forming-machine and is carried forwards by a trip bar,
64, mounted on the mould table, 65, of the forming-machine.
During this movement doors, 60, which close the bottoms of the
pockets, 12, are opened to discharge the charges of glass into the
parison mould. The bar, 64, is raised by a cam, 66, and after
the cups, 12, have discharged, the bar is allowed to fall and the
casing, 59, is returned to its normal position by a counterweight.
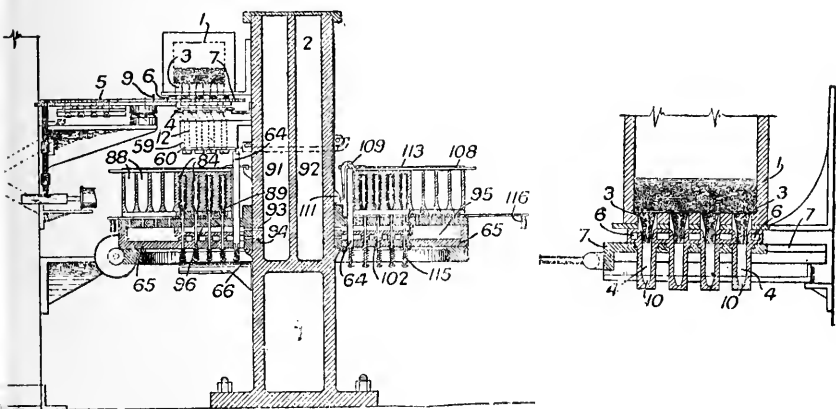
FIG. 169.

The mould table, 65, is rotated continuously about the central
standard, 2, and is made hollow to provide chambers, 95, 96. These
chambers allow communication between the moulds and chambers
91, 92, formed in the interior of the standard, 2, and connected
with suction and pressure devices respectively. Ports, 93, 94,
connect the chambers, 95, 96, with the chambers, 91 and 92, at
appropriate times. The table, 65, carries pairs of parison moulds,
84, and finishing moulds, 88, the moulds of each pair being arranged
radially with respect to one another and provided with a number of
moulding spaces. The ring moulds are carried by a sliding plate,
89, which is moved radially from one mould to the other by means
of a roller, 116, which engages a cam. Thus, the parisons are
formed, and the finished bottles are blown, neck downwards, and
there is no reversal of the parisons when transferring them to the
finishing moulds. The open ends of the moulds are covered by
plates, 108, pivoted on brackets, 109, carried by the moulds, and
opened and closed by a cam, 111. Openings are formed in the
plate, 108, over the parison moulds and these openings are closed,

after the moulds are charged, by sliding bars, 113. After the parison moulds have been charged by the feeding-device, the open ends of the moulds are closed and plungers, 102, are moved upwards into the ring moulds by the cam, 66, and suction is applied to pack the glass into the moulds. The plungers are next withdrawn by springs, 115, and compressed air is admitted to blow the parisons. The moulds are then opened and the ring mould plate, 89, slides outwards to transfer the parisons to the finishing moulds. After the final blowing, the moulds are again opened, and the ring mould plate is inverted by bevel gearing and then opened to discharge the bottles.   H. G. C.

392. Machine for the Manufacture of Bottles and other Blown Glassware. ÉMILE ROIRANT, St. Ouen, France, Assignor to ARTHUR WILZIN, St. Ouen, France (U.S.A. Pat., December 12th, 1922, No. **1438665**. Filed April 10th, 1919, No. 289012).—This specification relates to automatic machinery for the manufacture of bottles in which means are provided for varying the time during
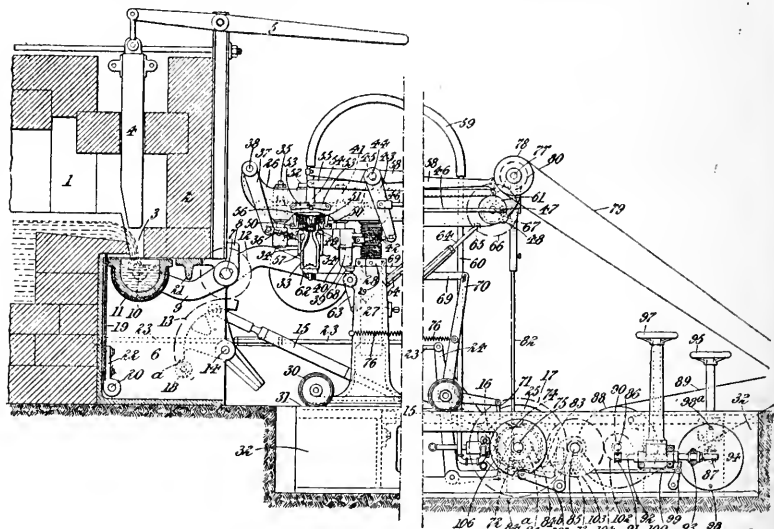
FIG. 170.

which the glass is in contact with the parison mould and with the finishing mould, the latter being varied without affecting the other cyclical movements of the machine.

Molten glass is allowed to flow from a melting furnace through an outlet, 3 (Fig. 170), into a transporter, 11. At the proper moment the flow of glass is stopped by a plunger, 4, and the transporter is swung outwards towards the axis of the moulds, until it arrives under the closed parison mould, 39, and the molten glass comes into contact with the base of the mould. When this happens, the cam, 107, operates a valve, 109, and places the parison mould in

connection with the vacuum chamber, thus sucking up glass to fill the mould. The stationary period of the transporter beneath the parison mould is varied by lengthening or shortening the operating rod, 15, thereby varying the stress to which the spring contained in the rod is subjected. As the crank pin, 16, continues its rotation the transporter is returned to its filling position. During the motion of the transporter from the mould, the cam, 74, comes into action and permits the knife, 68, under the influence of the spring, 76, to move forward quickly and sever the depending string of glass. The knife is returned by the action of the cam, 74, through the levers, 72 and 70, after which the cam, 84a, causes half a revolution to be imparted to the shaft, 67, thereby causing the parison mould, 39, to open, and the finishing mould, 33, to close about the suspended blank. At this stage, the cam, 108, operates the valve, 110, permitting compressed air to blow up the blank to the shape of the mould. After this a certain time is allowed for cooling before the mould is opened, this time being determined by the rate of rotation of the disc, 94. S. E.

393. A New Press–and–blow Machine. E. H. LORENZ, West Hartford, Connecticut, U.S.A., Assignor to THE HARTFORD-EMPIRE Co., Hartford, Connecticut, U.S.A. (Brit. Pat., No. **199377**, May 29th, 1923. Convention date, June 14th, 1922. Not yet accepted).—A press-and-blow machine comprises moulds carried by two intermittently rotated turrets, means for lifting the parison moulds into operative relation with the ring moulds at the pressing station, an automatic take-off device, and safety devices which stop the machine should an obstruction interfere with the proper working of the various parts. The machine comprises two turrets supported in a suitable framework, a blow turret, 67, for carrying the finishing moulds, ring moulds, bottom plates, and their operating mechanisms, and a blank turret, 66, for carrying the blank or parison moulds. The circular paths of these two sets of moulds touch at the pressing station, A, Fig. 172, where the parison is pressed and is transferred to the finishing moulds. The two turrets are geared together by gear rings, 113, 114, and are rotated intermittently by a helix cam formed on the surface of a power-driven drum, 110. In the operation of the machine, charges of metal from a suitable feeder pass by way of a shoot, 557, and a guide, 558, into a parison mould which is then moved by the rotation of the turret to the pressing station, A. The mould, which is carried by a slide, is elevated as it approaches the pressing-station, and is then lifted still higher, while at the same time the turrets are locked and an anvil is thrown into position below the mould to support it during the pressing operation. Meanwhile, one of the ring moulds, 157, carried by the blow turret, has been brought into position over the parison mould, and a plunger, operated by a compressed air cylinder, 200, descends and presses the metal, forming the parison and the neck ring. The anvil is then drawn back and the parison mould lowered, leaving the parison suspended by the ring mould. The turret then carries the parison to station *B,*

18—2

where a bottom plate, 276, is raised into position, and a finishing mould, 243, closes about the parison and ring mould. A blow-head, 313, descends on to the ring mould, and a valve is opened by a cam to admit compressed air to blow the parison, blowing taking place while the mould is moving to station E. At station F
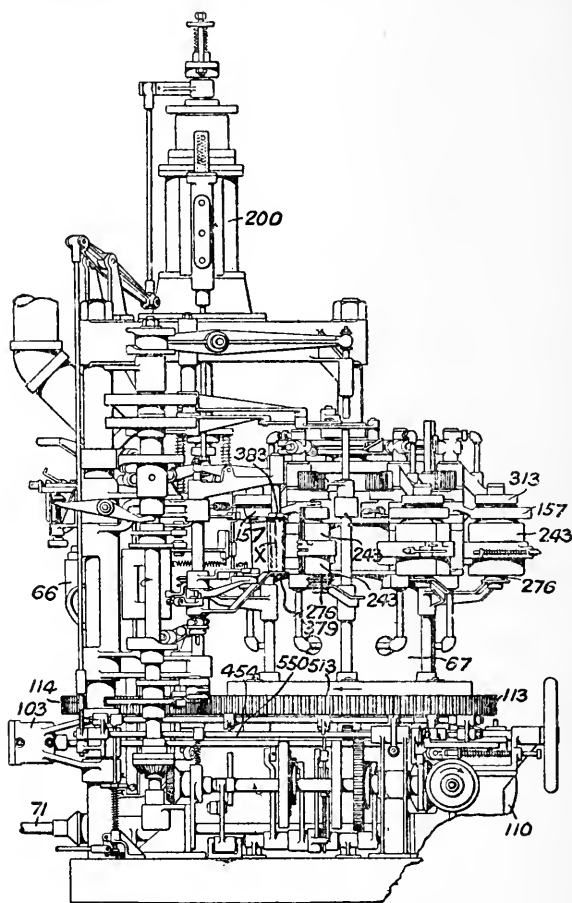
Fig. 171.

the mould is opened and the bottom plate is lowered, and a take-out device is swung inwardly, bringing a delivery plate, 379, Fig. 171, into supporting position beneath the finished article, X. A plug, 383, is then lowered into the article to steady it, the ring mould is opened to release the article, and the take-out is swung out-wardly, gradually releasing a cam-controlled delivery rod which, with the aid of the plug, pushes the article on to a receiving-table. Power to operate the machine is supplied to a driving-shaft, 71,

through a clutch which is opened or closed by a compressed air cylinder, 103. The clutch is provided with an overload release device, and can be opened by trips such as 550, 513, on a shaft,
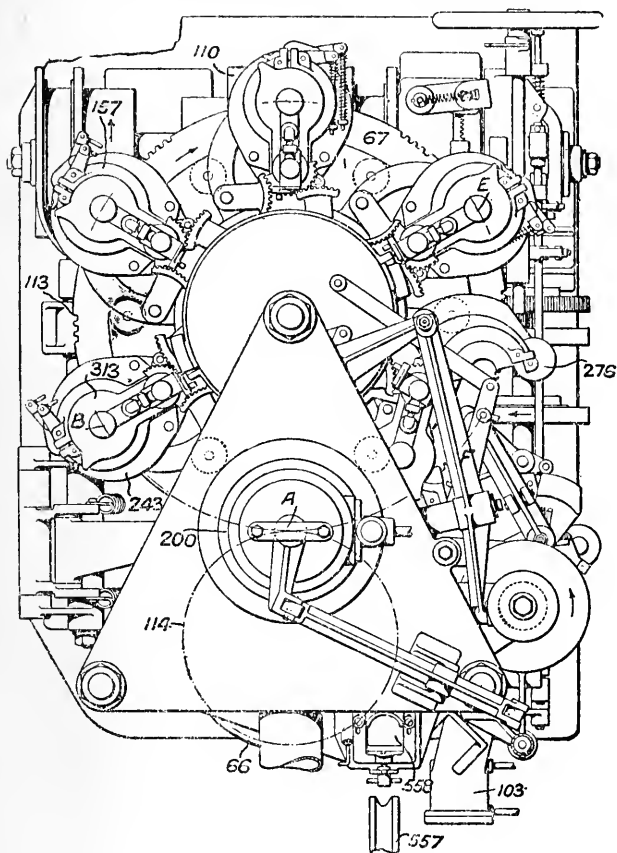
FIG. 172.

454. These trips are connected to the mechanisms performing the different operations in making the ware, and they are actuated to stop the machine should any of the mechanisms be obstructed or should there be any abnormality in their timing.   H. G. C.

394. An Automatic Feeding Device. C. H. RANKIN, Wellsburg, West Virginia, U.S.A. (Brit. Pat., No. **198952**, September 28th, 1922).—In a device for feeding molten glass towards and through a discharge orifice, the flow of glass is effected and controlled by a rotary archimedean screw dipping into or immersed in the molten glass. The device comprises a forehearth, a, having in the lower part a cup, b, fitted with a bush, c, forming the discharge orifice.

An archimedean screw, *d*, extends into the cup, *b*, and by its rotation assists or retards the extrusion of the metal through the bush, *c*. The screw is supported in bearings, *f*, carried by a bracket, *g*, which can be moved to raise or lower the screw to regulate the discharge. An adjustable sleeve, *j*, may surround the screw to co-operate in controlling the discharge and to serve as a dross trap or stop valve. Metal is led to the forehearth, *a*, from a pocket, *l*, by way of gutters, *k*, which feed the metal to diametrically opposite parts of the forehearth. The metal is raised into the pocket from a trough, *m*, by a second screw, *n*, which has its axis inclined at a convenient angle to the end wall of the trough.
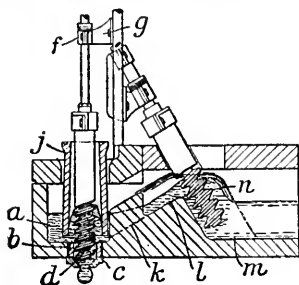
Fig. 173.

A further patent, by the same inventor (Brit. Pat., No. **202496**, July 26th, 1922), relates to a feeding-device of the kind comprising a throat-block, 1, and a nose cup, 4, having ducts or gutters, 7, arranged therein to deliver the glass in separate streams directed towards opposite sides of the delivery aperture, 13. According to the invention, adjustable gates or plugs, 9, are provided in the ducts, 7, to regulate the flow of glass. The throat block, 1, receives glass from a tank furnace through submerged apertures, 3, in one of its end walls, 2, which acts, therefore, as a trap to prevent entrance of scum from the metal in the tank. The nose cup is fitted to the other end wall of the throat block, the abutting walls, 5, 6, forming a dam in which two ducts, 7, are formed. The ducts lead the molten glass, as shown, around opposite sides of the sleeve valve, 14, and feeding-plunger, 15, so that the temperature of the glass is kept more uniform. The adjustable plugs, 9, enable the ducts to be closed or restricted to assist in regulating the temperature of the glass. The lower part of the nose cup is made conical and a removable corner, 20, is fitted. Orifices, 23, for the admission of gas flames are provided in various parts of the apparatus.
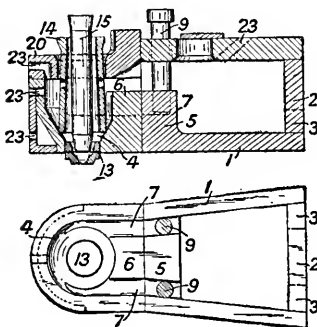
Fig. 174.

H. G. C.

395. A Machine for Finishing Bottle Necks. G. E. BATESON and H. A. BATESON, Victory Glass Works, Spekeland Road, Liverpool (Brit. Pat., No. **201000**, June 16th, 1922).—Relates to a machine for finishing bottle necks, of the type described in Specifications 8430/14 and 134801, in which a bottle blown in a mould

is placed in one of the pockets of a rotatable table on the machine and the neck is then melted and shaped. The pockets, 1, Fig. 175, are mounted on the rotating table, 2, and consist of brackets which are partly open on their radial sides and are completely open on their outer or peripheral sides. After a bottle has been deposited in a pocket, it is retained therein by circumferential band springs, 4, which extend from the filling station, a, to the discharging station, c, and thus close the outer sides of the pockets, 1. The bands are
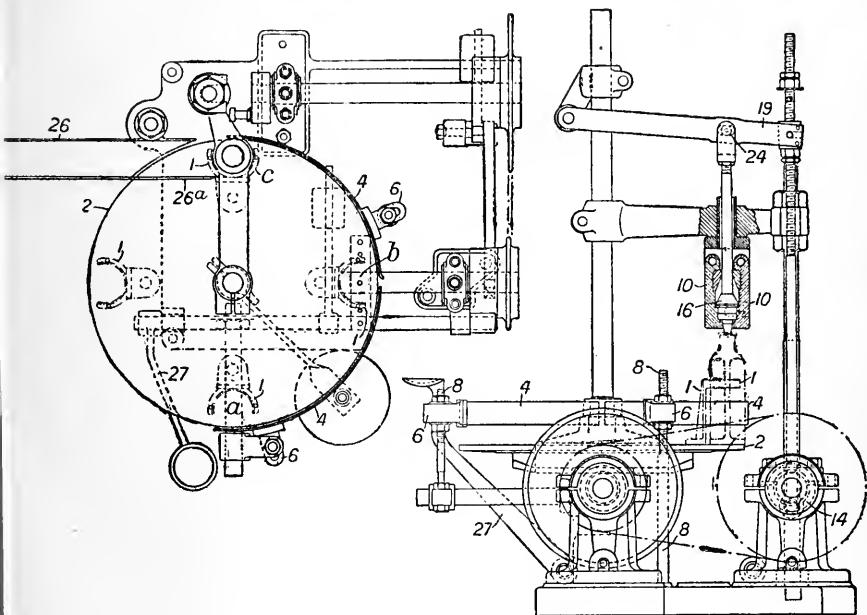
FIG. 175.

supported by brackets, 6, on long studs, 8, and they may be adjusted radially or vertically. At the station b the mouth of the bottle is softened by a bunsen flame, and at station c the softened mouth is shaped by the forming mechanism. This consists of a plunger, 16, to which forming-arms, 10, are pivoted, the top of the plunger being provided with a roller, 24, engaging a slot in a rocking-arm, 19, which is oscillated by an eccentric, 14. The bottles are removed from the pockets by means of the inner wall, 26a, of a shoot, 26. The wall projects into the path of the bottles and deflects them from the pockets into the shoot. A pedal, 27, operates a clutch for starting and stopping the machine.   H. G. C.

396. Process and Apparatus for Forming Glass Articles, R. W. ERDLE, New York, Assignor to THE COLD LIGHT MANU-FACTURING Co., Colorado, U.S.A. (U.S.A. Pat., December 26th, 1922, No. **1439698**. Filed April 5th, 1919, No. 287769).—The specification refers to the making of tubular glass containers of

self-luminous materials. A piece of glass tube sufficient in length to make two containers is placed on a carrier consisting of two sprocket chains which at intervals are joined by rods carrying rollers, and these are caused to rotate by the engagement of each end with a track arranged underneath the carrier. The tube is thus rotated and carried along over a series of burners, which are arranged so that the first pair seal up the two ends of the tube, and then another one heats the tube near its middle point, thus causing the enclosed air to expand the hot glass and produce an enlargement or bead. The article thus formed is cut in two through the central enlargement, giving two containers ready to receive the self-luminous material and the metal sealing cap.   S. E.

397. An Automatic Feeder. E. T. FERNGREN, Beaver, Pa. (U.S.A. Pat., No. **1415824**, May 9th, 1922. Filed January 24th, 1914, No. 814066).—The invention consists of a feeding-device in which a charge of metal is fed into a preliminary former which shapes the charge and transfers it to a parison mould. The invention also comprises means for chilling the interior of the stream of metal and for heating its exterior in order to prevent uneven chilling of the skin of the charge and to secure proper distribution of the metal in the finished article.
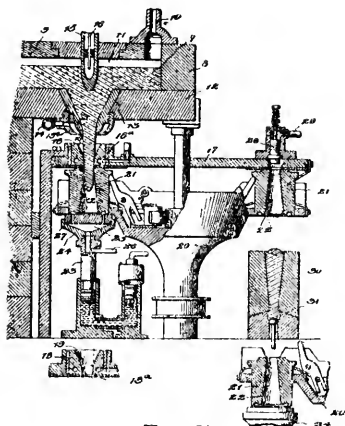
Fig. 176.

The metal is fed in a stream through an outlet, 13, in the bottom of a forehearth, 8, and the flow is regulated by a water-cooled regulator, 15, vertically adjustable in the metal, which forms a cooler zone in the body of the metal that extends downwards towards the interior of the issuing stream. The regulator, 15, may be reciprocated, if desired, to cause a cessation of the flow of the stream when a charge is separated.

The outlet is surrounded by a burner, 13a, which directs a flame on to the issuing stream. The chilled skin, formed on the stream by contact with the outlet, is thus remelted and the consequent uneven distribution of glass in the finished article is prevented. The stream passes into a funnel member, 18, carried by a plate, 17, below which an intermittently rotatable turntable, 20, is arranged. This turntable, 20, carries a number of preliminary blank-formers, 21, each of which, as it comes to rest below the outlet, 13, is elevated by a plunger, 23, into contact with the plate, 17. The plunger has a hollow head, 24, provided with a suction chamber, 25, through which the air in the former, 21, can be exhausted. The stream of metal flows through the funnel into the former, 21, and is caused to fill it by suction. The turntable then rotates one step, thus

causing the edge of the former and the funnel to shear through the stream of metal, the cut end of which is retracted by the elasticity of the metal. The filled former, 21, comes to rest below a plunger, 28, which is moved downwards by compressed air and causes the charge of metal to fall into a parison mould, 30.

The shearing of the stream may be accomplished by shears of the usual construction instead of using the edges of the former and the funnel, and in this case the funnel and the use of suction may be dispensed with. Compressed air acting directly on the charge may be used instead of the plunger, 28, to extrude the charge. G. D.

398. A Flow Feeder. S. DAVIDSON and THE SCHRAM GLASS MANUFACTURING Co., St. Louis, Missouri (U.S.A. Pat., No. **1458167**, June 12th, 1923. Filed January 29th, 1921, No. 440915).—A feeding device comprises a cup for receiving a flowing stream of glass and accumulating a charge, a knife which opens and closes the bottom of the cup, and means for jolting the cup when opened in order to free the charge and ensure that it is dumped into the mould.

The cup, 37, Fig. 177, is supported beneath a funnel, 33, in a casting, 29, in such a way that it is free to rotate and to move vertically. A shear blade, 41, slides beneath the cup and is moved at appropriate times by a compressed air cylinder. The lower edge, 40, of the cup is bevelled, as shown, so that the weight of the cup causes the edge to make contact with the cutting edge of the shear blade. The blade moves across the cup bottom and makes contact with a guide lip,

FIG. 177.

58, the inclination of which is adjustable so as to direct the tail of the severed glass properly into the mould.
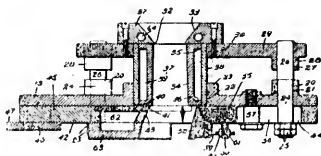
The device is mounted above the mould table of a machine which is brought beneath a boot of a tank so that a stream of glass runs into the cup. The stream collects in the cup until the blade is withdrawn from beneath it. The bevelled edge, 40, then allows the cup to drop a little and at the same time the cup is given a rotary movement by a flexible pipe connecting the water jackets of the blade and the cup. The combined twisting and dropping movement of the cup frees the accumulated charge of glass and ensures that it is dumped into the mould. G. D.

399. Means for Feeding Charges of Molten Glass. R. LA FRANCE, Toledo, Ohio, Assignor to THE OWENS BOTTLE COMPANY, Toledo, Ohio (U.S.A. Pat., No. **1439369**, December 19th, 1922. Filed August 11th, 1920, No. 402816).—Glass is allowed to flow in a continuous stream from a melting furnace, 11 (Fig. 178), through an opening, 14, in the base of a small extension or spout, 12, into a basin or receptacle, 15. This basin is mounted to rock

about a horizontal axis, and for this purpose is fitted with trunnions journalled into the metal framework, 17. The rate at which glass flows into the basin is controlled by the plug, 19, which is capable

Fig. 178.

of adjustment vertically. The basin is rocked on its bearings by the cam, 25, which is secured to the continuously rotating shaft, 24, causing a reciprocating movement of the arm, 27. As the basin rocks, the head of glass over the outlet, 29, is alternately increased and diminished. As the head of glass increases, the rate of outflow increases, causing the glass to be extruded in the form of a gob, whilst as the glass recedes the rate of outflow is diminished, and the flow of glass away from the orifice exerts an upward pull on the glass in the outlet.
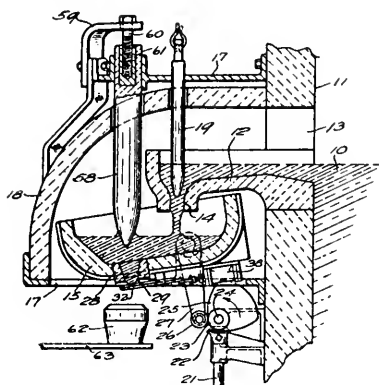
At this moment the gob is severed by a pair of pneumatically operated shears, 32.

The flow of glass from the outlet, 29, may be further controlled by the plunger, 58, the height of which may be adjusted by the screw, 60. The relative motion between the basin and this plug helps in forming the gob.   S. E.

400. Improvements in Flow Feeders. W. G. Clark, New York (U.S.A. Pat., No. **1458522**, June 12th, 1923. Filed May 27th,

Fig. 179.

1920, No. 384654).—The invention consists of electrical devices for heating the glass in a forehearth or feed trough, particularly for remelting the cold glass left in the trough after a shut-down. In the construction shown in Fig. 179, an electric resistance element, 9, is built into the wall of the trough, 10, and is connected by leads, 12, 13, with the current supply. In another construction, the leads, 12, 13, are connected to terminals which are submerged in the glass at opposite ends of the trough. The operation of this form of the invention depends on the fact that molten glass conducts electricity and is heated by the passage of the current. The two forms of the invention can be used together.
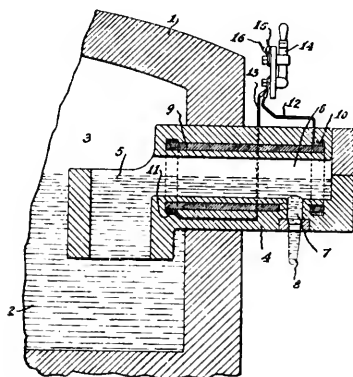
                                                                G. D.

401. Apparatus for and Method of Producing Charges of Molten Glass. L. D. SOUBIER, Toledo, Ohio, Assignor to THE OWENS BOTTLE Co., Toledo, Ohio (U.S.A. Pat., No. **1428994**, September 12th, 1922. Filed December 20th, 1920, No. 413848).— The glass feeder described in this specification is claimed to have special value for the production of large charges or gobs of glass of comparatively narrow section such as are required for making battery jars and large bottles. At the same time, by a special provision, this feeder can be used for delivering quite small globular charges of glass such as are required for making fruit jar covers.

FIG. 180.

Molten glass is supplied from a furnace, 11 (Fig. 180), to an extension, 12, from which it is discharged through an outlet opening, 13. The flow of glass is controlled by a regulator in the form of a vertically reciprocating plunger, 14, the downward movement of which assists in expelling a quantity of glass, whilst the upward movement retards the flow.
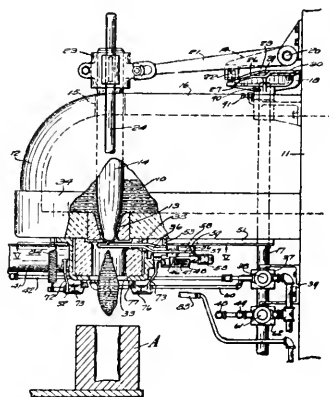
Mounted on a continuously rotating shaft, 17, is a cam, 18, on which runs a roller, 22, secured to an arm, 19, which in turn is secured to the arm, 21. This arm, 21, at its outer end has an operating connection with a yoke, 23, which is slidable between vertical guides, 24, and carries a plunger, 14. The cam, 18, is so designed that a complete reciprocation of the plunger may be made during about a half-revolution, the plunger being held stationary in its upper position during the other half-revolution. The upward movement of the plunger is not continuous, as in one position it remains steady for a short time, corresponding to the flat section, 28, on the cam.

Mounted on the bottom of the boot is a cylinder, 32, of refractory material surrounding the outlet, 13, and provided with an opening, 35, through which shears, 36, enter and sever the completed gob of glass. The shears are carried to their cutting position by means of a compressed air operated piston. Towards the end of the movement of this piston, the shears as a whole are brought to rest, and the further movement of the piston causes them to close against the action of a spring. On the return stroke, the shears first open, and then retract.

During the upward movement of the plunger, a sliding plate is brought under the mouth of the cylinder, 32, and a vacuum connection is made, thus exhausting the air from this chamber and causing the molten glass to begin to flow at once even although the plunger is moving upwards. As soon as the plunger reaches the top of its stroke, this plate is removed and the downward movement

is begun, thus forcing the glass through the orifice and maintaining the diameter of the gob which was started by the vacuum. The plunger, having completed its downward stroke, immediately begins to retract thus causing a restriction in the flow of glass and a narrowing of the gob in the place where the shears sever it. For the production of small ware the plunger may be held stationary thus partly closing the outlet, and the gobs are then formed by the action of the vacuum.   S. E.
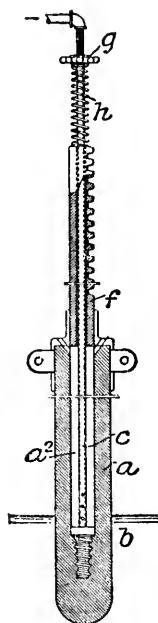
FIG. 181.

402. A Plunger for Use in an Automatic Feeding Device. F. O'NEILL, Toledo, Ohio, U.S.A. (Brit. Pat., No. **199805**, March 28th, 1922).—A plunger for use in an automatic feeder, particularly that described in Specification 179977, is supported from its lower end, in addition to being supported from its upper end, by means that permit of differential expansion and contraction. The plunger, a, is of refractory material and is clamped at its upper end to a tubular rod, f, which is formed as a rack to enable the plunger to be reciprocated. A tube, c, extends through the tube, f, and an axial bore, a^2, in the plunger, and is secured at its lower end to the plunger by means of a plug, b, of heat-resisting metal. A spring, h, is mounted on the tube, c, between the upper end of the tube, f, and a nut g, which is screwed on to the tube, c. The spring allows differential expansion between the tubes c and f and the plunger, and its pressure may be adjusted, thus preventing parts of the plunger from breaking away in the event of fracture. The tube c may be perforated at its lower end to allow air to be circulated through the tube and the bore in the plunger.   H. G. C.

403. Guides for Transferring Glass to Moulds. L. D. SOUBIER, Toledo, Ohio, Assignor to THE OWENS BOTTLE CO., Toledo, Ohio (U.S.A. Pat., No. **1439384**, December 19th, 1922. Filed April 30th, 1920, No. 377770). —In order to guide gobs of glass as delivered by a feeder into the moulds of a continuously rotating machine, two funnel-shaped guides, 26 and 27 (Fig. 182), are mounted on a continuously rotating horizontal shaft, 28. These guides are oppositely disposed, and arranged so that the wider ends come beneath the feeder outlet, and the lower or constricted ends over the parison
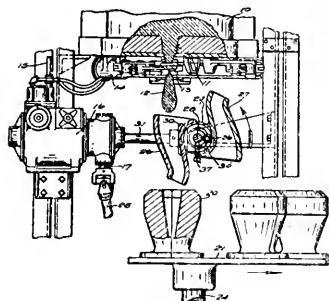
FIG. 182.

moulds, 29. The rate of rotation of these guides is such that the lower end remains in register with the parison moulds over a considerable arc, thus allowing sufficient time for the delivery of the gobs to the moulds even on fast-moving machines.   S. E.

404. A Device for Ejecting Finished Ware from Moulds. E. H. LORENZ and K. E. PEILER, and THE HARTFORD-FAIRMONT COMPANY, Canajoharie, New York (U.S.A. Pat., No. **1406045**, February 7th, 1922. Filed March 29th, 1917, No. 158242).—The
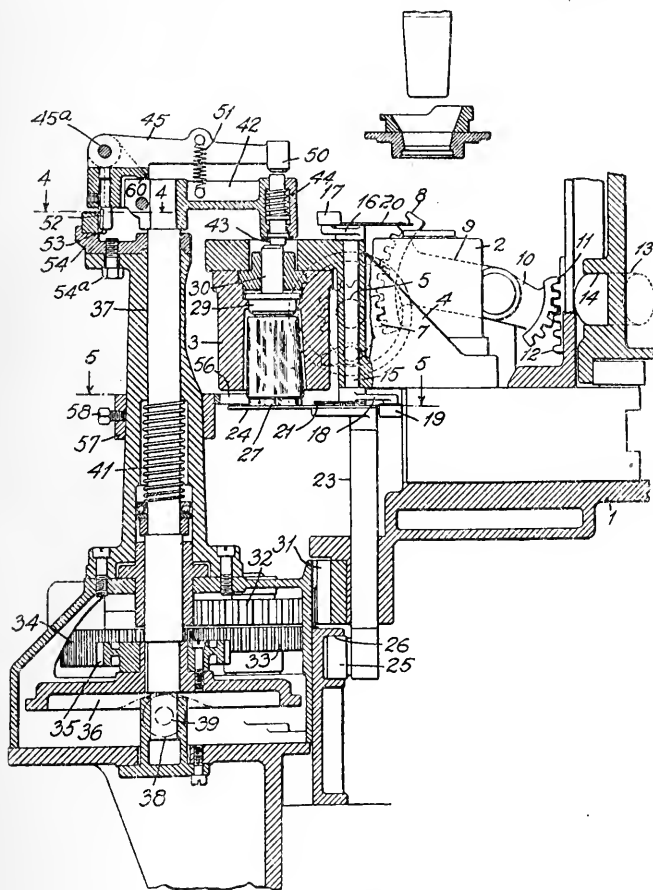
FIG. 183.

invention consists of a device which will ensure the ejection of finished articles from the moulds of a forming-machine and thus prevent interference with the machine operation due to an article sticking in a mould.

The device shown in Fig. 183 applied to a press in which the

moulds are arranged in pairs, 2, 3, formed in a block that is inverted to eject the finished article from one mould and to present the other mould for receiving a charge of metal. The finished article, 27, is ejected on to a receiving-plate, 24, which is brought up beneath the mould and is then lowered with the article to the take-off position. To ensure ejection, a resiliently mounted plunger, 43, is lowered and pressed against the stem, 30, of the mould bottom, 22. In addition, a hammer, 50, pivoted above the plunger, is caused to strike a succession of blows on the upper end of the plunger. Should the combination of pressure and percussion not be sufficient, an elastic arm, 56, that lies in the path of the rim of the article, tilts the article sideways to ensure that it does not stick to the mould bottom, 29.

G. D.

405. The Control of and Lubrication of Mould Plungers. C. R. LOTT, Washington, Assignor to THE OWENS BOTTLE Co., Toledo, Ohio (U.S.A. Pat., No. **1439372**, December 19th, 1922. Filed March 15th, 1920, No. 365786).—According to this specification, a plunger in the form of a hollow core surrounds a pipe which is provided with perforations, so that cooling air supplied through the pipe is uniformly distributed throughout the interior of the shell or plunger. If, on the other hand, the plunger requires keeping warm, combustible gas may be fed into its interior and burned there, or an electrically heated coil may be placed round the central pipe.

For lubrication purposes, or for external cooling, a tube may be disposed in the form of a ring around the plunger and above the mould, so that as the plunger is descending atomised oil may be sprayed on to its exterior surface.   S. E.

406. A Glass–severing Mechanism. R. LA FRANCE, Toledo, Ohio, Assignor to THE OWENS BOTTLE COMPANY, Toledo, Ohio (U.S.A. Pat., No. **1439368**, December 19th, 1922. Filed September 4th, 1917, No. 189458. Divided and this application filed March 13th, 1920, No. 365422).—The chief object of this invention is to provide means for severing the charge of plastic glass in a suction mould from the depending " tail," wherein the knife is actuated by a piston motor and speed multiplying gears, thus giving a quick and positive action to the cutter. The piston rod is attached to a rack which engages a pinion wheel, to which is geared another pinion meshing with a second rack carrying the cutter on the end of an arm. When compressed air is passed into the cylinder, forcing the piston forward, the knife is thus moved forward quickly underneath the parison mould. Before the blade is withdrawn it is given a short vertically downward movement by means of a fixed cam on the framework of the machine.   S. E.

407. A Shearing Mechanism for Glass-making Machines. R. F. HALL, Wythall, near Birmingham (Brit. Pat., No. **199414**, December 23rd, 1921).—In a machine in which the parison moulds open at the bottom, are lowered on to the surface of the molten

glass, the trailing glass being cut off by a pivoted or sliding knife, the mould is adapted to be raised to an intermediate position in which the cut-off is effected, the mould being then raised from the knife before the return stroke of the latter. In the form shown, in which the machine is of the type described in Specification 164763, the mould, 52, is carried on to a counterbalanced arm, 47, operated by a cam, 22, on the central pillar, 16. The cam is shaped so that the mould is made to halt between its extreme lowered position, 52b, and its raised position, 52a, at the position 52, in which the knife, 109, is operated; on the elevation of the mould to the position, 52a, the knife is

Fig. 184.

returned. The cam may be formed of removable sections of varied contours to vary the timing of the operations and the invention may be applied to machines in which the moulds are carried by vertically reciprocating secondary frames. Specification 165112 also is referred to.   H. G. C.
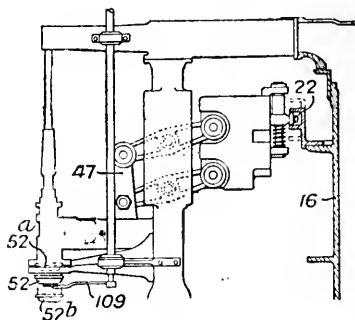
408. A Porous Glass Mould. H. T. Davis, 115 Lewisham Road, London (Brit. Pat., No. **199558**, May 4th, 1922).— A porous mould for blowing glassware consists of an outer shell, *A*, perforated with vent holes, *C*, and lined with a layer, *B*, of shredded metal packed into place. Granulated mineral matter, such as asbestos, graphite, lime, magnesia, or silica, may be mixed with the shredded metal to regulate the degree of porosity.
                                                           H. G. C.
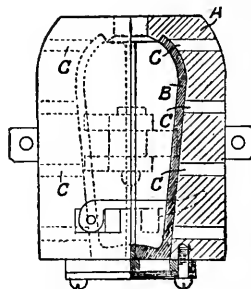
Fig. 185.

409. Process for Making Hypodermic Syringes. F. X. Nowak, Brooklyn, New York (U.S.A. Pat., No. **1445641**, February 20th, 1923. Filed November 3rd, 1919, No. 335393).—A length of tube is rotated on rollers, and one end heated until softened. A tool, similar to a bottle-neck tool, is then brought up to the heated end, where its centre pin fits into a recess in a plug maintained inside the glass tube. The action of

Fig. 186.

the tool and plug produces a square end with a slightly tapering aperture, 4. The glass end plug, 5, with the usual fine bore, 8, and the piston, 2, are then ground to fit the tapered orifice, 3, and the cylinder, 1, respectively.   S. E.
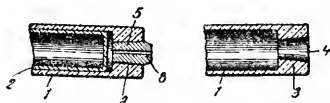
410. Machine for Vacuum Tube Manufacture.   A. Board-MAN, Hamilton, Canada, Assignor to THE WESTERN ELECTRIC Co., New York (U.S.A. Pat., No. **1438941**, December 19th, 1922. Filed October 16th, 1919, No. 330987).—This invention relates more particularly to a machine for sealing the electrode supporting stems of vacuum lamps or valves to the external glass bulbs,

Fig. 187.

and provides means for ensuring that the stem is sufficiently heated before the neck of the bulb is sealed on to it.
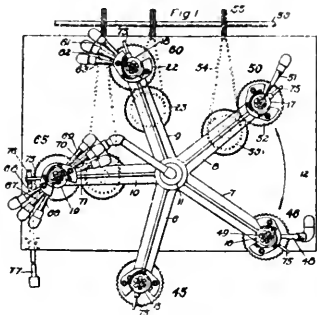
The machine comprises a plurality of arms, 6, 7, 8, 9, and 10, mounted on a rotatable shaft, 11, carrying at their extremities bulb-holding frames with spring clamps. The bulbs are inserted, open neck downwards, at the position, 45, and at the same time the stem is mounted on a support inside the neck. On moving to the position 46, a flame, 48, warms up the stem to the desired temperature, and then the arm passes on to position 50, at which the bulb is rotated and a flame, 51, warms up its neck. After this preliminary heating, the head moves on to position 60, where three flames, 61, 62, and 63, heat a narrow band of the neck of the bulb. The final heating takes place at position 65, where six burners cause the constricted portion of the neck to collapse and become sealed to the flared portion of the stem, after which the assembled lamp or valve is removed from the machine.   S. E.

411. Syringe Handle Forming Machine.   H. N. HALVERSEN, Vineland, New Jersey, Assignor to THE KIMBLE GLASS Co., Chicago,
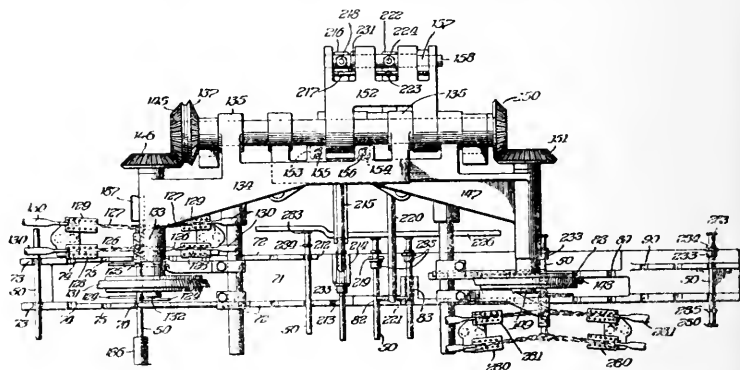
Fig. 188.

Illinois (U.S.A. Pat., No. **1443470**, January 30th, 1923. Filed January 26th, 1920, No. 354304).—Glass rods, 50, Fig. 188, are fed from a magazine in turn and brought step by step up to the anti-

friction rollers, 124 and 125. The frame, 134, then swings down bringing the revolving bevelled rubber disc, 131, into contact with the rod, causing it to rotate, and at the same time holding it up against a pusher, 186, which acts as a gauge. When the rotating rod has been sufficiently heated by gas flames at two separated points, the supply of gas is cut down, and the rear pusher rod approaches the front one, thus enlarging the glass at points 283 and 284. The driving disc, 131, is then raised and the partly completed rod is carried forward by the reciprocation of the plate, 226, until it reaches the support, 214, where it is held in position by the member, 215, and is in alignment with a wire, carrying rubber plugs one of which, 233, is transferred to the glass rod by the plug shifter. The rod is now passed on towards a second set of anti-friction wheels, and in going, the plug is moved towards the other end of the stem by the members, 236 and 237. On the second set of rollers the glass is again heated in two places near the other end and two enlargements, 285 and 286, are formed in much the same way as the first pair were formed. The finished rod is then taken step by step to the delivery end of the machine. S. E.

412. Apparatus for the Manufacture of Glass Canes. W. WESTBURY, Okmulgee, Oklahoma (U.S.A. Pat., No. **1439855**, December 26th, 1922. Filed February 16th, 1920, No. 359033). — Molten glass is drawn from the surface of the glass in a tank, through a cooling apparatus fixed through the crown of the furnace. This cooler comprises a hollow head and tubular hollow stem, and is made of iron with a protective layer of refractory material such as fireclay. Water is circulated through this cooler by means of the pipes, 8 and 13. In carrying out the operation, the portion of the surface of the glass is cooled, and the cane is drawn from the spot thus cooled, through the water-

FIG. 189.

cooled cylinder so that in the first stage of its formation it is rapidly cooled to ensure its setting. The upward drawing of the cane is accomplished by the rollers, 10 and 11. S. E.
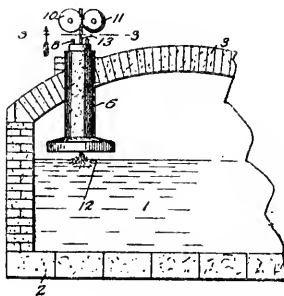
413. Thermionic Valve Manufacture. F. C. FISCHER and THE WESTERN ELECTRIC CO., New York (U.S.A. Pat., No. **1409339**, March 14th, 1922. Filed October 15th, 1919, No. 330783).—The specification relates to the manufacture of thermionic valves ("vacuum tubes") in which the filament and the grid and anode, of the type used in America, are supported by a glass rod which projects from the side of the stem tube. The invention consists of a jig for ensuring the proper positioning of the rod in respect to the stem tube. G. D.

414. Thermionic Valve Manufacture. A. G. JILLARD, S. BRACKEN, and THE WESTERN ELECTRIC Co., New York (U.S.A. Pat., No. **1396759**, November 15th, 1921.   Filed September 18th, 1919, No. 324489).—The invention relates to the glass block with metal or wire insets that support the elements of a thermionic valve (" vacuum tube ").   In carrying out the invention, the wire insets are first prepared to form their ends into anchorage, and the glass block is then moulded around the prepared ends.

A mechanism constructed according to the invention comprises a pair of dies for pressing the glass block into the desired shape, mechanism for feeding and cutting the wires and forming the ends, and mechanism for removing the finished block.

G. D.

415. Drawing Sheet Glass. J. WHITTEMORE and THE LIBBEY-OWENS SHEET GLASS Co., Toledo, Ohio (U.S.A. Pat., No. **1447702**, March 6th, 1923.   Filed November 10th, 1919, No. 336875).— A method of making sheet glass consists in drawing a sheet downward from a mass, sustaining the plastic sheet from the drawing point, and tensioning or flattening the sheet by deflecting it, while still plastic, into a substantially horizontal position beneath a smooth flattening surface.

As shown in Fig. 190, metal from the tank A forms a shallow pool on a horizontal tile, C, from the lip, Q, of which it is drawn away in a sheet, P, by drawing mechanism, I. On leaving the lip of Q, the sheet is deflected downwards and passes beneath a bending roll, J. The process thus differs from the Colburn process in that the sheet passes beneath instead of passing around the bending roll. Thus the weight of the plastic portion of the sheet is not carried by the bending roll, and the pressure between the sheet and the roll can be arranged so that it is sufficient to flatten the sheet without being sufficiently great to produce marring of the sheet.
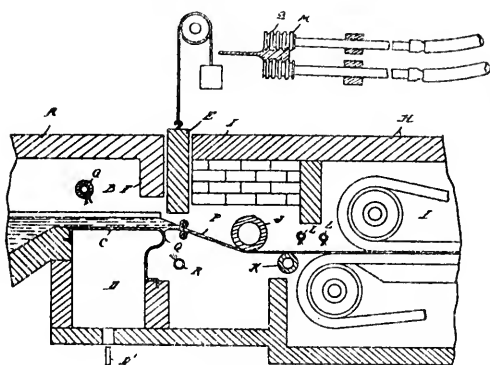
FIG. 190.

After leaving the lip, Q, and before reaching the bending roll, the edges of the sheet may be passed between corrugated rolls, M, to maintain the width of the sheet.   These rolls instead of being driven, as in the Colburn process, may be idlers or may even be braked in order to apply a slight drag to the edges of the sheet.

G. D.

416. Drawing Sheet Glass Automatically. W. GRAY and THE LIBBEY-OWENS SHEET GLASS Co., Toledo, Ohio (U.S.A. Pat., No. **1450590**, April 3rd, 1923. Filed July 10th, 1920, No. 395246). —An apparatus for drawing sheet glass consists of a forehearth from which the sheet is drawn, an endless sheet-carrier which consists of flat plates hinged together, and guides that cause the carrier to travel vertically above the drawing point and then turn horizontally.

The carrier, as shown in Fig. 191, consists of flat plates, 14, which are hinged together and are suspended by hangers, 9, from endless chains, 7, that are guided in a rectangular path. The plates run through a cooling tank, 15, on their lower run, and on their vertical run, *A*, above the forehearth, 6, support the sheet, *S*, which rests
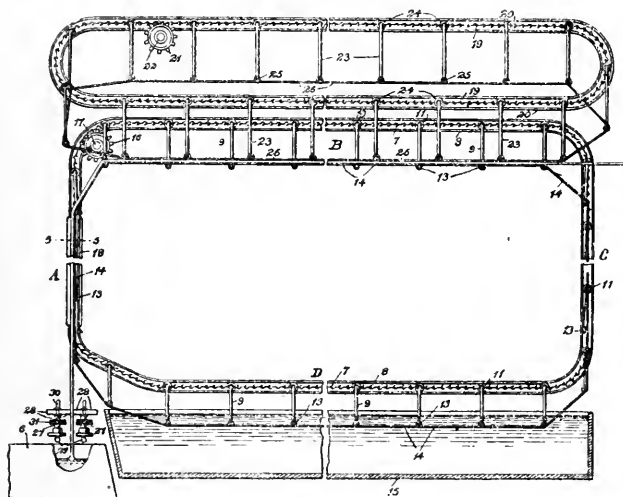
FIG. 191.

against the outer face of the plates. When the plates turn into the upper horizontal run, the plastic sheets still rest against them and are further pressed into contact by means of a series of presser-plates, 26, carried by chains, 24. The sheet is then drawn off by suitable mechanism.

In order to prevent the sheet from narrowing, it is engaged at its edges, just above the forming-point, by radial arms, 28, that project from vertical shafts, 29. These shafts are driven in unison by suitable means, and the arms, 28, engage the edges of the sheet and pull them outwards.

A further specification by the same inventor (U.S.A. Pat., No. **1449038**, March 20th, 1923. Filed January 26th, 1921, No. 440086) describes means for maintaining a predetermined width of the sheet.

The device consists of two endless chains, 16, somewhat longer than the endless carrier, 11, but supported and guided thereby except during the lower horizontal run. These chains, 16, pass around a guide roller, 20, and then vertically upwards close against the edges of the sheet. Teeth, 22, formed on the chains, press against the edges of the sheet and clamp them against other teeth formed on other endless chains which are located on the opposite face of the sheet. The edges of the sheet are thus gripped at a position immediately above the drawing-point, and are prevented from tapering-off or narrowing under the strain of the drawing-operation.

G. D.
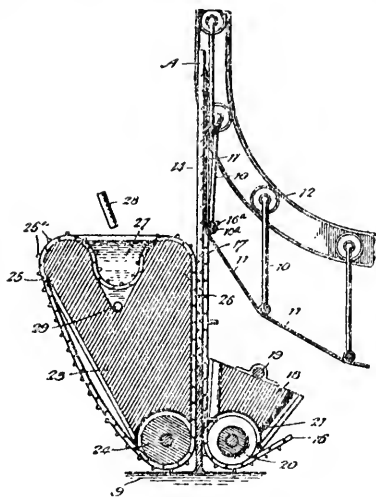
Fig. 192.

417. Modifications in Machines for Drawing Sheet Glass. W. J. Mellersh-Jackson, Southampton Buildings, London (Libbey-Owens Sheet Glass Co., Nicholas Building, Toledo, Ohio, U.S.A.) (Brit. Pat., No. **201429**, August 24th, 1922).—Relates to sheet-drawing apparatus, particularly of the type described in Specification 114977, in which the sheet is drawn upwards from a mass of metal, and after passing over a bending-roll, proceeds over the drawing-table consisting of an endless conveyor against which the edges of the sheet are pressed by grippers on another endless belt. According to the present invention, the grippers are replaced by a number of rollers, 20, which are positively driven and press the edges of the sheet, 1, against the moving drawing-table, 12. The rollers are mounted at the ends of shafts, 21, which are journalled in pivoted arms, 22. The rollers are also supported by springs, 23, the compression of which can be adjusted to vary the pressure of the rollers on the sheet. The shafts, 21, may be cooled by air blown through them from supply pipes, 45. The rollers, 20, may be covered with asbestos.
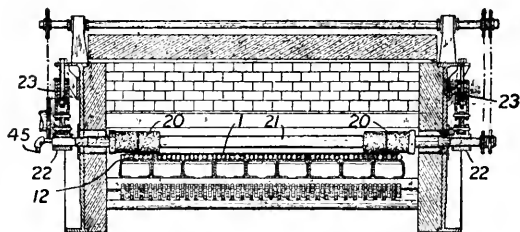
Fig. 193.

H. G. C.

418. Automatically Drawing Sheet Glass. W. J. MELLERSH-JACKSON, 28, Southampton Buildings, Chancery Lane, London (LIBBEY-OWENS SHEET GLASS Co., Nicholas Building, Toledo, Ohio, U.S.A.) (Brit. Pat., No. **199881**, April 28th, 1922).—Relates to a process of drawing sheet glass in which the lateral parts of the sheet are guided, on leaving the mass of glass, in such a manner as to maintain the edges in a predetermined direction, and consist in arranging that the sheet of glass itself drives the width-maintaining mechanism. The device consists of a series of sliding grippers which continuously hold out the edges of the sheet and stretch it laterally during the forming period, and they also act as a drag on the edges of the sheet. The glass sheet, 3, is drawn upwards from a receptacle and passes over a bending-roll, 4, as described in Specification 114977. Edge-forming rolls, 5, are
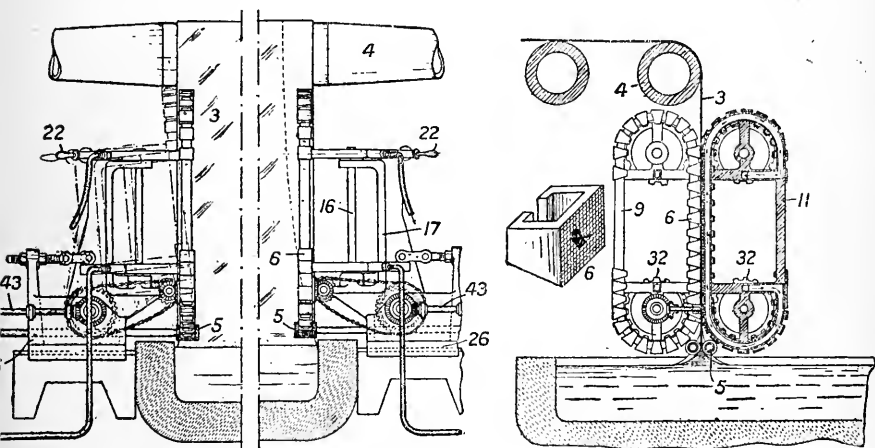
FIG. 194.

arranged at or near the source of each edge of the sheet, and above these are arranged water-cooled guides, 9, 11, on which grippers, 6, Fig. 194, are free to slide. The guides, 9, 11, are pivoted in a vertical shaft, 16, carried by frames, 17, and can be moved away from the sheet by handles, 22. The frames are closed by springs to bring them against the sheet. In operation, the frames are closed on the sheet and press the grippers, 6, against the sheet edges. The grippers are carried upwards by contact with the sheet and thus prevent it from becoming narrower during the period in which it is formed. The grippers slide over the upper parts of the guide and are returned to the lower ends by gravity. Gear wheels, 32, mounted close against the lower loops of the guides, 9, 11, and driven from a shaft, 43, engage the grippers and feed them into contact with the sheets. The frames, 17, are mounted on sliding carriages, 26, and they may also be tilted to enable the lateral tension on the sheet to be adjusted. In a modification, the grippers

move up and down vertical guides which are arranged in pairs on each side of the sheet. The guides of each pair are alternately moved away from the sheet by cams for a sufficient time to allow the grippers, which have moved up the guides, to slide down to their initial position.   H. G. C.

419. Improvements in the Colburn Process. J. C. Crowley and The Libbey-Owens Sheet Glass Co., Toledo, Ohio (U.S.A. Pat. (Reissue), No. **15452**, September 12th, 1922. Original No., 1342533, filed July 8th, 1918. Serial No., 243981).—In a sheet-
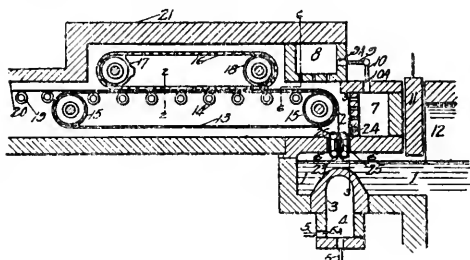
Fig. 195.

drawing apparatus of the Colburn type, the draft mechanism consists of endless chains, 16, and an endless metal belt, 13, which is stretched over driving drums, 15, and prevented from sagging on its upper run by means of supporting-rolls, 14. The temperature of the glass at the drawing-point is regulated by means of a fire-box, 4, heated by liquid fuel burners, and consisting of a chamber with a domed top, 3, which projects into the metal. Another fire-box, 7, heats the sheet, 2, in the drawing-chamber before it is bent into the horizontal position. Endless chains, 23, forced into contact with the edges of the sheet by springs, grip the edges and maintain the width of the sheet.

                                        G. D.

420. A New Method for Automatically Drawing Sheet Glass. O. M. Cox, Manayka, and C. C. Rose, Clarksburg, W. Va., (U.S.A. Pat., No. **1423195**, July 18th, 1922. Filed February 25th, 1920, No. 361129).—A machine for drawing glass in flat sheets comprises a frame which can be moved into position above a container for the molten glass, a number of reciprocating members carried by the frame, and means carried by these members for alternately gripping and releasing the sheet, the grippers working in proper sequence so that the sheet is drawn continuously.

The reciprocating members consist of blocks, 31, which can slide vertically between upright bars, 30, forming part of the frame. The blocks are connected in pairs by horizintal bars, 34, wrapped with asbestos string, that form part of the devices for gripping the sheet S. The remaining part of each gripping device consists also of a horizontal bar carried by bell-crank levers, 39, one of which is pivoted on each block, 31. The free arm, 40, of each lever is connected to a link, 42, that is pivoted eccentrically on a gear wheel, 43, which is mounted on the frame alongside the uprights, 30. Worms, 43, on driving shafts, 47, gear with the wheels, 43, and drive them in unison. It can be seen that when

the motion of the wheels carry the blocks, 31, downwards, the grippers are opened and slide over the sheet, S, but in the upward movement of the blocks, the grippers close on and draw the sheet. As shown in Fig. 196 successive grippers are arranged in different positions relatively to one another, so that at least one pair of grippers is always drawing the sheet.
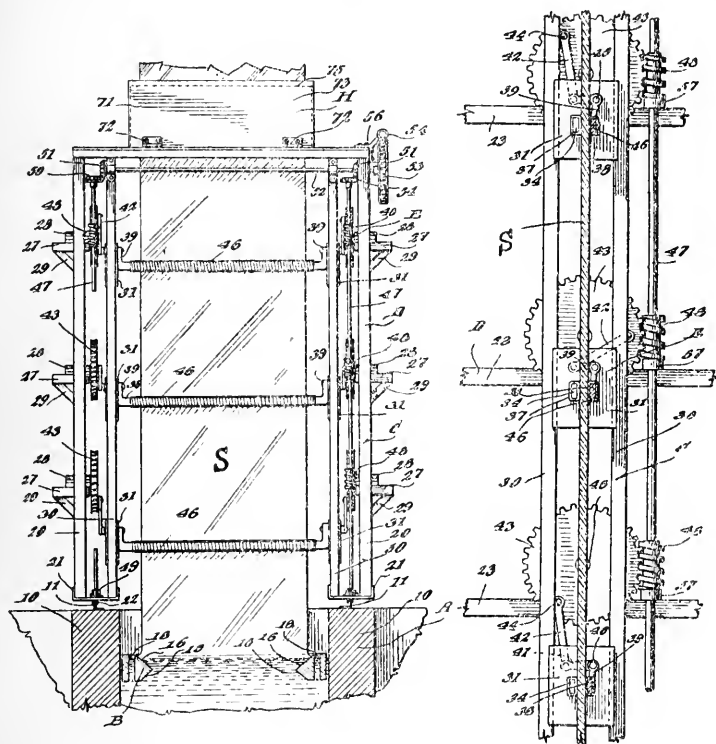
FIG. 196.

The sheet, as it rises above the top platform of the frame passes between the members, 73, of a cutting bench, 4, where it is cut into lengths.

In order to prevent the sheet from narrowing during the draw, a rectangular frame, B, floats in the metal. The sides of the frame are enclosed to form an angular section, 15, 16, that anchors the sheet.   G. D.

421. Improvement in the Drawing Block used in the Four-cault Process. SOC. ANON. BREVETS FOURCAULT, Dampremy, Belgium (Brit. Pat., No. **202576**, December 22nd, 1922).—Relates to the Fourcault process of drawing sheet glass in which the sheet, f, is drawn through a slot in a block, z, of refractory material. According to the invention, the recess, e, in the block, instead of

being uniform in cross section, is made broader towards the ends, the drawing slot, d, being kept of uniform width as before.   This
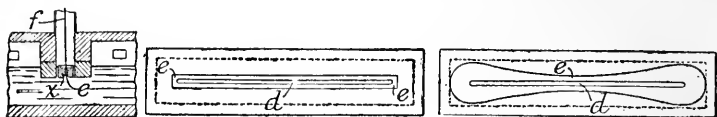
FIG. 197.

arrangement is stated to avoid the lack of uniformity in the thickness of the sheet, due to the lower temperature of the metal along the walls of the tank.   H. G. C.

422. Changing the Rollers in Sheet Glass Machines. W. J. MELLERSH-JACKSON (Brit. Pat., No. **201444**, September 16th, 1922).—Relates to the process of drawing sheet glass, described in Specification 114977, in which the sheet is drawn vertically upwards and is then passed over a bending-roller, whence it proceeds horizontally.   The bending-roller has a very smooth surface which eventually becomes tarnished and must then be replaced.   The present invention consists of a method of replacing the bending-roller by another without interrupting the production of sheet glass.

The bending-roller, 5, Fig. 198, is journalled at its ends in bearings,
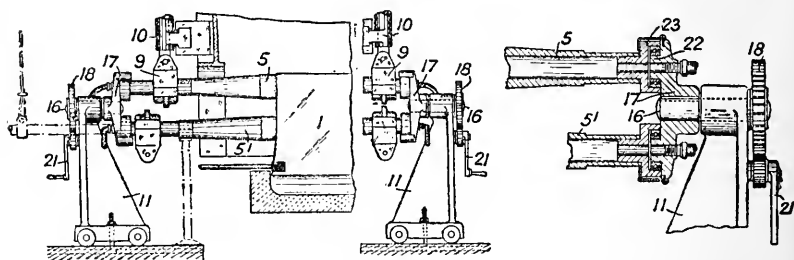
FIG. 198.

9, which are hung from adjustable supports, 10, at the sides of the tank.   The device for changing the rollers consists of members, 11, which can be wheeled to the side of the tank and locked in position. Each member, 11, supports a short shaft, 16, to one end of which is keyed a double bracket, 17, whilst at the other is secured a gear-wheel, 18, that can be rotated by a hand crank, 21.   The bracket, 17, carries at its end studs, 22, on which bearing-rings, 23, are freely rotatable, and the bearing-rings fit into the ends of the bending-roller, 5.

In changing a roll, the member, 11, is run up to the sides of the tank and locked in place with a ring, 23, fitted into the end of the roll, 5, as shown.   The new roll, 5', which has been heated to the correct temperature, is brought parallel with and beneath the roll, 5, but not in contact with the sheet, 1, the end of the roll being

fitted on to the second ring, 23. The second member, 11, is then fitted to the other ends of the rolls, 5, 5', and locked in position. The bearings, 9, are then freed from the supports, 10, and by turning the cranks, 21, the brackets, 17, can be turned through 180° and the rolls interchanged. The old roller is then removed. H. G. C.

423. Apparatus for Automatically Cutting Glass Sheets. W. J. MELLERSH-JACKSON, 28, Southampton Buildings, London (LIBBEY-OWENS SHEET GLASS Co., Nicholas Building, Toledo, Ohio, U.S.A.), (Brit. Pat., No. **199653**, October 10th, 1922).—An apparatus for scoring and dividing sheets of glass comprises a conveyor band, 3, Fig. 199, moving the sheets, 1, from a lehr, 2, and a carriage,
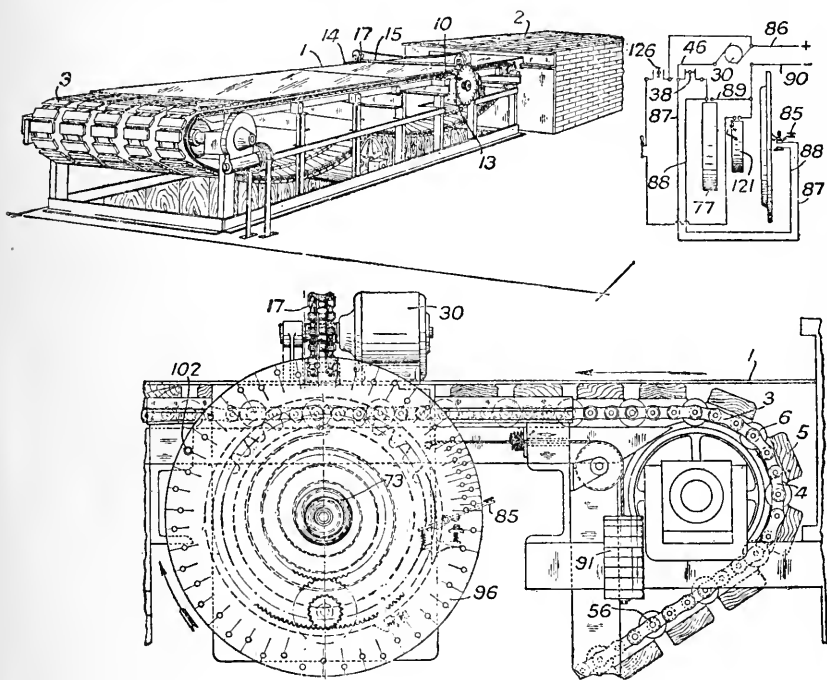
FIG. 199.

13, 14, automatically coupled to travel with the conveyor, 1, while the sheet is being scored, the scoring tool moving simultaneously in the transverse direction.

The sheet-carrying band, 3, comprises wood blocks, 5, mounted on chains, 4, guided by rollers, 6, and carrying rollers on pintle extensions, 56. The scoring-tool carriage, 13, 14, has rollers, guided on rails, 10, mounted on opposite sides of the main frame, and a cross-connection, 15, forming a guide for scoring-tool carrying-chains, 17, which pass over sprockets on the carriage. On the member, 15, are switches, 126, 38, actuated by lugs on the chain.

The carriage, 13, carries a gear, 58, constantly in mesh with rollers on the chain, 55, and, loosely mounted on a shaft, 59, to which it can be coupled by a clutch, 62, actuated by a spring, 75, and de-clutched by a hand-moved cam, 73. A clutch member, 119, keyed to the shaft, 59, co-operates with a loosely mounted clutch member, 120, with teeth, 117, turning, through gears, 116, 115, 112, a spring-urged graduated disc, 96. An electro-magnet, 121, is provided for breaking the clutch, 119, 120, and another electro-magnet, 77, locks the gear, 58, against rotation on the shaft, 59, causing the gear and the carriage, 13, 14, to be moved with the conveyor. The apparatus
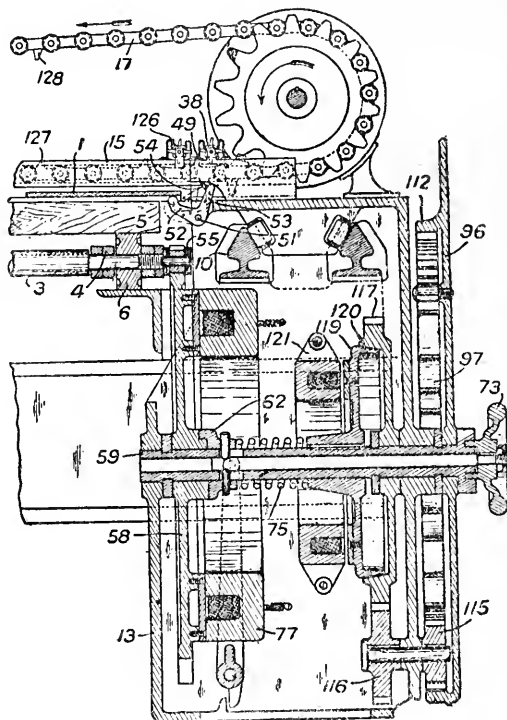
Fig. 200.

operates as follows : When the cutting mechanism is idle, the clutch, 62, is out and the gear, 58, turns idly. To cut a length of, say, 60 inches, a peg, 102, is placed in a hole on the graduated disc, 96, the hand wheel, 73, turned to permit engagement of the clutch, 62, and a hand switch, 85, Fig. 199, pressed to complete the circuit, 86, 30, 46, 87, 85, 88, 77, 89, 90, energising an electro-motor, 30, driving the chain, 17, and the electro-magnet, 77, and thus causing the carriage to travel with the moving sheet and the scoring-tool to operate. A lug (not shown) on the chain immediately actuates the switch, 38, allowing the contact, 85, to be released but the

circuit maintained. While the score is being made, another lug, 127, engages a switch, 126, to close a circuit through the electromagnet, 121, unclutching the gear, 117, and allowing the disc, 96, to be restored to its zero position by the spring, 97. A lug, 128, now actuates the switch, 126, and breaks circuit through the electromagnet, 121, allowing the spring, 75, to reset the clutch, 119, 120. After the scoring is completed a lug, 54, actuates the arm, 53, of a cracking lever, 52, 53, and a lug, 49, operates the switch, 38, breaking circuit through the motor, 30, and magnet, 77, thus stopping the chain and allowing the carriage to be restored to its starting position by a mass, 91. During the carriage return movement the gear, 58, rolls along the chain, 55, as the disc, 96, is rotated until the peg, 102, again depresses the starting switch, 85. The various lugs on the chain and the scoring-tool are duplicated. Specification 114977 is referred to. H. G. C.

424. A Cylinder-capping Device. W. WESTBURY, Caney, Kansas (U.S.A. Pat., No. **1458452**, June 12th, 1923. Filed January 19th, 1922. No. 530479).—Relates to the process of severing glass cylinders into suitable lengths, and consists of a device that is particularly intended for cracking cylinders the walls of which are of uneven thickness. The device consists of an electrically heated wire 1, which embraces the cylinder and is divided into sections, 3, 4. The sections are connected at one end to terminals 6′ on a lead, 5, and at their other ends to a block, 10, provided with a switch, 11. This switch enables either or both the sections, 3, 4, to be heated

FIG. 201.

separately. The operator can adjust the length of the sections and can control the time during which each of them is heated and is thus enabled to heat the cylinder in such a way as to secure an even crack. G. D.
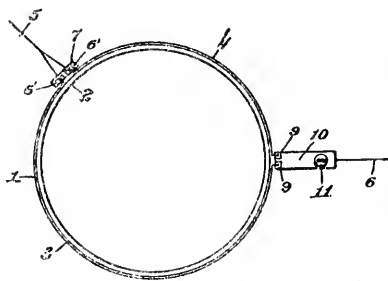
425. Rounding Glass Edges. F. COTTERELL, Melbourne, Australia (Brit. Pat., No. **200545**, March 9th, 1922).—A plate of glass, 14, the edge of which is to be rounded, is rested on a wooden slab, 13, on a horizontal table, 12, and it together with the slab is moved so that the edge of the glass is kept in contact with a peripheral groove, 1, in a grinder, 2. The grinder is provided with a flanged socket, 4, detachably secured to a vertical spindle, 5, and may be replaced by a similar wooden disc

FIG. 202.

for polishing the edges of the work. Specifications 20473/89 and 2034/95 are referred to. H. G. C.
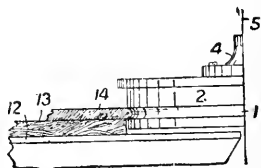
426. Modified Apparatus for Polishing Glass. W. TAYLOR, and KAPELLA, LTD., 104, Stoughton Street, Leicester (Brit. Pat., No. **198472**, March 16th, 1922.   Addition to No. **126489**).—The apparatus described in the parent specification is modified so that it operates under conditions which sometimes arise with polishes made of felt, etc., when the friction between the polisher and the work increases as the supply of liquid or liquid and abrasive is increased.   The air-pipe connecting the dynamometer to the cylinder, which operates the needle-valve controlling the supply of lubricant, etc., is transposed to the opposite end of this cylinder and thus produces the reverse effect on the piston.   The apparatus can be further modified to give a warning to an attendant, for example, by connecting the air-pipe to a pneumatic indicator; an electric bell or lamp may be used, the circuit thereof containing a contact on the dynamometer.   Upon the receipt of the signal the operator may control the supply of lubricant, etc., by means of a valve inserted in a pipe conveying compressed air to the cylinder which operates the aforesaid needle-valve.   Alternatively, or in addition, a pencil may be attached to the dynamometer to trace a graph of the variations of friction and so to give an indication of the necessity, or otherwise, for fresh lubricant.   The apparatus can be modified still further by utilising the variations of load on the electric motor driving the polishing machine to operate a switch controlling an auxiliary circuit.   Such auxiliary circuit is used either to control the supply of liquid or to operate a warning signal.

H. G. C.

427. Glass Grinding Fixtures. B. W. BARISH (*Glass Industry*, 1923, **4**, 166).—An arrangement was described whereby lenses
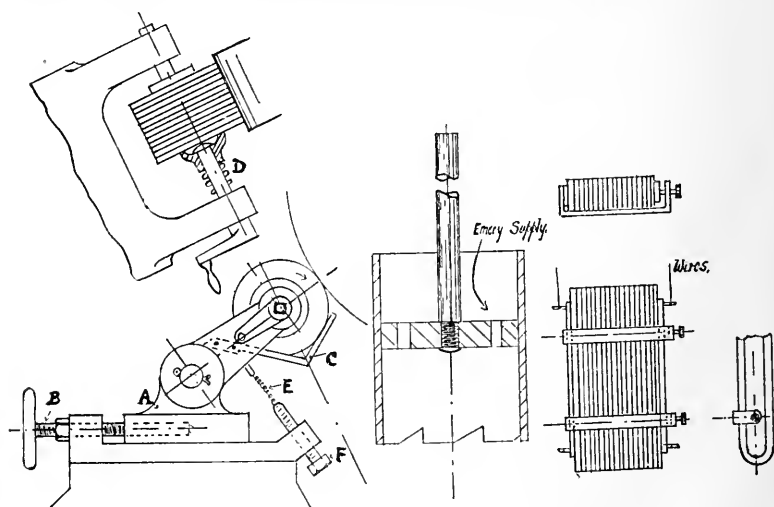
FIG. 203.

could be ground to gauge (Fig. 203). Bracket *A* could be adjusted by means of a screw, *B*, the lenses being placed between the clamping

jaws and centred by means of an angle, C (not shown in plan). D was a clamping spring, E a tension spring, and the screw, F, regulated the friction between the lenses and the grinding wheel. The process needed careful attention.

For cutting holes in bullet-proof glass, a cylinder of brass tubing with notches at the grinding end was used.

For rounding the ends of rectangular bars, a number were clamped together and suspended from the ceiling, so that they could be readily reversed after one end had been treated.   W. C. S.

428. Grinding Non-spherical Lenses. R. V. MORSE (*J. Optical Soc. Amer.*, 1923, **7**, 705).—The lens, L, having been ground to a suitable spherical shape, was placed in the apparatus shown and pressure applied below, causing it to bulge upwards, the amount of displacement from the spherical contour being controlled by the cross section of the glass and the pressure applied. While so deformed it was ground by the tool, T, in the usual way to a fresh spherical contour. The pressure

FIG. 204.

was then removed and the glass sprang back, thus modifying its original shape by an amount quite sufficient to alter considerably its optical performance. This method was suggested for eliminating some of the usual aberrations of the spherical lens.   M. P.
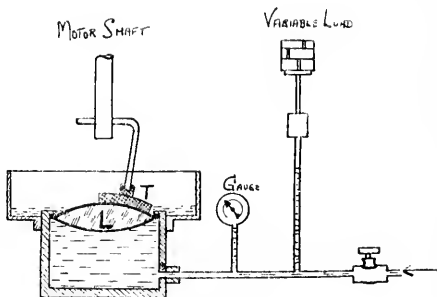
X. Glassware Accessories.

429. Metal Caps for Glassware. H. S. BRADY (*Glass Ind.*, 1923, **4**, 183).—The strength and the ductility of the metal used had to be considered, as well as the calculated size of the blank. The "stretch" varied with the metal used, and in an example given, the true blank diameter should be $2\frac{1}{4}$ inches, or $\frac{3}{64}$ inch less than a straightforward calculation would have indicated. If the cap had to be threaded or given a curled or wire-edge, allowance must be made in the original blank, or else warping would result. As annealing would spoil the finish on the metal, the only cure lay in the prevention of such faults.   W. C. S.

XI. General.

430. A New Window–glass House. R. KNORRN (*Zeitsch. Verein. deut. Ingenieure*, 1923, **67**, 513).—The article dealt with the solution of local and technical problems arising in connection with the construction of a new hand-made window glass factory at St. Ingbert in the Palatinate, having one melting tank, 12 glory holes, and 14 flattening furnaces. The waste heat from the tank exit gases and from the glory holes was used to heat water for power and heating apparatus. The steam passed first to a steam plant to generate direct current electricity and then as exhaust steam to the gas producers. Variations in power and heat requirements were met by a storage battery and by temporarily admitting fresh gas to the six glory-hole boilers. The cinders from the producers were used in the same works to make cement–lime–cinder bricks. H. W. H.

Reviews.

Imperial Mineral Resources Bureau. The Mineral Industry of the British Empire and Foreign Countries. Statistics 1919–1921. The following Reports have been issued recently :—
Aluminium (including Bauxite and Cryolite). Pp. 35. 1*s.*
Bismuth. Pp. 13. 9*d.*
Coal, Coke and By-products. Pp. 141. 4*s.* 6*d.*
Copper. Pp. 74. 3*s.*
Gold. Pp. 46. 1*s.* 6*d.*
Graphite. Pp. 20. 1*s.*
Iron and Steel. Pp. 47. 1*s.* 6*d.*
Lead. Pp. 60. 2*s.*
Petroleum and Allied Products. Pp. 149. 7*s.* 6*d.*
Quicksilver. Pp. 19. 1*s.*
Silver. Pp. 41. 1*s.* 6*d.*
Strontium Minerals. Pp. 7. 6*d.*
Tin. Pp. 48. 1*s.* 6*d.*
Zinc. Pp. 64. 2*s.*
These Reports may be obtained from His Majesty's Stationery Office, Kingsway, London, W.C.2, at the net prices quoted.

G. S. D.

Scientific and Industrial Research for the Year 1922–23.—A Report of the Committee of the Privy Council, H.M. Stationery Office, London. Price 4*s.* net.
The Annual Report of the Department of Scientific and Industrial Research has now grown to considerable dimensions. In this case

it has 141 pages and records very wide and growing activities. It is divided into three sections, the first of which is the report of the Committee of the Privy Council itself, dealing with general policy, the second the report of the Advisory Council, which again discusses policy and general progress, whilst the third section gives a more detailed account of the particular advances made by various Research Boards and Research Committees. A series of eight appendices gives statistics concerning the constitution of the Research Boards, of grants to individual research workers and students in training, of aided researches and industrial researches, publications by persons in receipt of grants, of developments in the organisation of research in the Dominions, of the names of Research Associations, of State-aided research in France, and a list of departmental publications.

The activities of the Department have undergone some change of direction since its work was originally instituted. Its aim at the outset was to stimulate the formation of Research Associations, in which manufacturers would, it was hoped, take a leading part. This particular effort appears to have borne much less fruit in the last two years than was originally anticipated, and since 1921 only one new Research Association, namely, the Flour Milling Research Association, has come into definite being. The main cause for the rather slower progress than was anticipated is the depression in trade, which has been a great obstacle to the contribution of sufficient funds to make new Research Associations possible. The report discusses other factors which are necessary to the success of existing Associations, and one gets the impression that rather more fruitful results were expected than have actually materialised. It must, of course, be remembered that the war period, during which the scheme got launched, was necessarily one during which most manufacturers were prepared to utilise every item of scientfic knowledge. The demonstration of the power of science was a remarkable one, but very few manufacturers ever had a clear understanding of what scientific research means, or how slowly it produces tangible results. It seems to the reviewer that concurrently with any attempt to develop and utilise researches there must be a great effort to raise the standard of knowledge of the fundamental principles underlying industrial processes.

A good deal of energy has been thrown into the scheme of Research Boards which serve directly under the ægis of the Department and are controlled by scientific workers of national reputation.

Finally, the grants given to students in training are worthy of special mention, for they are most valuable in developing the research potentialities of the country. It is pointed out in the report that students of chemistry preponderate amongst those to whom grants have been given in the past, and in view of the considerable unemployment existing in this particular profession, it may be necessary to restrict the number of awards to post-graduate students in chemistry and to encourage biologists and physicists, for whom there do exist openings in industry.

W. E. S. T.

Der Wärmefluss in Einer Schmelzofenanlage für Tafel-glas. HEINRICH MAURACH (Munich and Berlin, R. Oldenbourg, 1923), pp. 96, with 28 illustrations and one plan.

Ever since the signing of the treaty of peace the great need in German industries has been for fuel. Industry, no longer having available the full resources even of the existing German coal-fields, has had to turn to inferior sources of fuel and to making the most also of the limited amount of better class fuel obtainable. So far as the glass industry is concerned, the result has been to force the question of the economical use of fuel to the very forefront. It was this problem that gave rise to the foundation of the Wärmetech-nischen Beratungsstelle der Deutschen Glasindustrie in Frankfurt, and ultimately last year to the German Society of Glass Technology. This advisory bureau on efficient heating has already issued a number of reports based on surveys of individual works conditions, and the result has been to bring about very considerable improvement in the efficiency of fuel consumption.

Dr. Maurach, who has been so closely identified with the move-ment, gives us in this book the result of a detailed study of a single glass-works engaged in producing sheet glass. The study is minute and precise, and for those of our readers who have sufficient facility in reading German, the reviewer strongly recommends a study of this book. The outcome of the study was to show that only 12·8 per cent. of the heat supplied by the fuel system was usefully employed in melting and maintaining the glass at the necessary working temperature, whilst the loss of heat in the waste gases was considerably more than twice this amount. This fact alone, as the author points out, indicates what room there is for big advances in the efficient application of heat to the melting of glass.

W. E. S. T.

JOURNAL

OF THE

SOCIETY OF GLASS TECHNOLOGY

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